NUCLEAR POWER IN CALIFORNIA: 2005 STATUS REPORT

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Prepared By:
MRW & Associates, Inc.

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Prepared By:
MRW & Associates, Inc.
Robert B. Weisenmiller, Steven C. McClary and
David N. Howarth
Oakland, California
Contract No. 700-02-004

Prepared For:
California Energy Commission

Barbara Byron
Contract and Project Manager

Sandra Fromm
Assistant Program Manager, 2005 Energy Report

Kevin Kennedy
Program Manager, 2005 Energy Report

B.B. Blevins
Executive Director

Abstract

This consultant report provides background and factual information on California's nuclear power plants and key nuclear power issues such as nuclear waste storage, disposal, and transportation. The report reviews the federal and state regulatory framework for nuclear power and the various agencies that oversee nuclear power plants and related issues. The report examines the costs and benefits of continuing to operate California's aging nuclear power plants. Financial, safety, and security issues are key considerations in assessing the going-forward costs and benefits associated with nuclear power. Storing and disposing spent nuclear fuel is a major challenge for nuclear power plant operators; thus, the report reviews the status of federal efforts to develop a federal geologic repository at Yucca Mountain as well as utilities' interim nuclear storage options. In considering the future role of nuclear power in California, policymakers must consider certain trade-offs such as whether nuclear power can be part of the solution to curbing greenhouse gas emissions despite potential safety or security risks. Finally, the report offers some preliminary findings for policymakers to consider.

Keywords

nuclear, nuclear power, nuclear waste, spent fuel, interim spent fuel storage, reprocessing, Yucca Mountain, Diablo Canyon, San Onofre, SONGS, Humboldt Bay, Rancho Seco, NRC, DOE, electricity, policy, California, Warren-Alquist

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ACRONYMS AND ABBREVIATIONS

A&G	administration and general
AEC	Atomic Energy Commission
ASLB	Atomic Safety and Licensing Board
CAISO	California Independent System Operator
CCC	California Coastal Commission
CDHS	California Department of Health Services
CDOT	California Department of Transportation
CEPA	California Environmental Protection Agency
CEQA	California Environmental Quality Act
CHP	California Highway Patrol
CPCN	certificate of public convenience and necessity
CPUC	California Public Utilities Commission
DOE	Department Of Energy
DOT	Department of Transportation
Energy Report	*Integrated Energy Policy Report*
EPA	U.S. Environmental Protection Agency
GAO	Government Accountability Office
GHG	greenhouse gas
GWh	gigawatt-hour
HLW	high-level radioactive waste
ICIP	incremental cost incentive price
IEPR	Integrated Energy Policy Report
ISFSI	independent spent fuel storage installation
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
LOCA	Loss of Coolant Accident
MIT	Massachusetts Institute of Technology
MRS	monitored retrievable storage
MSR	molten salt reactor
MTHM	metric tons of heavy metal
MW	megawatt
NAS	National Academy of Sciences
NCEP	National Commission on Energy Policy
NEIL	Nuclear Electric Insurance Limited
NEP	National Energy Policy
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
NWF	Nuclear Waste Fund
NWPA	Nuclear Waste Policy Act
NYMEX	New York Mercantile Exchange
O&M	operating and maintenance
ORA	Office of Ratepayers Advocates
PFS	Private Fuel Storage LLC
PG&E	Pacific Gas and Electric
PSDAR	post-shutdown decommissioning activities report
RPS	Renewable Portfolio Standard

SCE	Southern California Edison
SCWR	Supercritical Water Reactors
SDG&E	San Diego Gas & Electric
SGR	steam generator replacement
SGRP	Steam Generator Replacement Project
SMUD	Sacramento Municipal Utility District
SNF	spent nuclear fuel
SONGS	San Onofre Nuclear Generating Station
TECWG	Transportation External Coordination Working Group
TRU	transuranic waste
TURN	The Utility Reform Network
VAR	volts-ampere-reactive
WGA	Western Governors' Association
WIPP	Waste Isolation Pilot Plant

EXECUTIVE SUMMARY

California and the Energy Commission were at the forefront of the national nuclear debate in the 1970s when the state's nuclear plants were being licensed. At that time, policy concerns focused on nuclear waste disposal, nuclear fuel reprocessing, and (in California) seismic risks. Policymakers felt these issues had not been fully addressed prior to the licensing of the state's nuclear power plants. In 1976 the Legislature enacted laws requiring operational and approved waste disposal and fuel reprocessing options before construction of additional nuclear plants in the state could take place. The Energy Commission was charged with evaluating those options and ultimately concluded no operational and approved federal waste disposal or fuel reprocessing options existed, a finding supported by subsequent events. A moratorium on building new nuclear plants in California remains in effect today.

This report examines the last thirty years of developments in the nuclear industry as they relate to California. It considers the histories of California's nuclear plants and the costs and benefits of continuing to operate them. It also examines the status of the nuclear waste issue and other financial, safety, and security issues that may impact California's nuclear energy future.

Status of California's Plants

California depends on three nuclear power plants for a sizable share of the overall electricity supply in the state. These three plants alone generate 13% of California's annual electricity supply, and the two in-state nuclear plants are the second and third largest power plants in the state. (Energy Commission 2004b) Pacific Gas and Electric (PG&E) owns and operates the Diablo Canyon nuclear power plant, a 2,160 MW plant with two units licensed through 2021 (Unit 1) and 2025 (Unit 2). Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E) co-own the San Onofre Nuclear Generating Station (SONGS), a 2,200 MW power plant with three units. SONGS Units 2 and 3 are licensed through 2022; Unit 1 was shut down in 1992. SCE, the Los Angeles Department of Water and Power, and a consortium of southern California municipal utilities have a combined ownership interest of 27% in the Palo Verde nuclear power plant, which is a 3,825 MW plant located outside of Phoenix and operated by Arizona Public Service Corporation. Palo Verde's three units are licensed through 2024, 2025, and 2027.

Four commercial nuclear power plants are located in California. Two of these plants (Rancho Seco and Humboldt Bay) are no longer operating. California's two active nuclear power plants, Diablo Canyon and SONGS, began commercial operation in the mid-1980s and have now been operating for about 20 years. The California Public Utilities Commission (CPUC) is currently considering applications by PG&E and SCE to replace the steam generators at both of these plants. Replacement of the steam generators, along with other substantial investments in turbines, other major pieces of equipment, and ongoing plant worker recruitment and training efforts, are necessary for continued, reliable operation of these plants. In addition, these repairs and upgrades may extend the useful lives of these two plants by at least 10 years. Eventually, the operators of these power plants may apply to the federal Nuclear Regulatory Commission (NRC) to extend the original operating licenses. Thirty-two of the 103 commercial U.S. reactors have already been granted 20-year license renewals by the NRC. (CEN 2005)

Costs and Benefits of California's Nuclear Power Plants

Continuing to operate California's nuclear plants provides certain benefits to the state as well as engendering costs.

Benefits of California's Nuclear Plants

Nuclear power currently provides about 13% of the state's power. This power is cheaper than power from most other power sources, and it emits fewer greenhouse gases. Using nuclear power enhances the state's fuel diversity and reduces its demand for natural gas. Furthermore, the southern California grid is highly dependent on the SONGS plant and might require significant upgrades if this plant were shut down.

Value of Energy and Capacity

The energy and capacity supplied to California by nuclear power plants has value that is reflected in the cost that would have to be incurred to replace that energy and capacity in the event that the existing nuclear plants are shut down. In its steam generator replacement proceeding, PG&E has estimated that shutting down the two Diablo Canyon units in 2013 and 2014 would incur about $3.1 billion (2003 dollars) of replacement power costs through 2025. In its steam generator replacement proceeding, SCE has estimated that shutting down the two SONGS units in 2009 would incur about $5.2 billion (2004 dollars) in replacement power costs through 2022. Intervenors in these proceedings have argued that the utilities have exaggerated these figures.

Grid Reliability

Diablo Canyon and SONGS provide reliable sources of baseload power for the state. What would happen were they to shut down? The California ISO has studied this question and found that SONGS appears to provide substantial grid reliability benefits as a result of its location between the SCE and SDG&E service territories, and that significant transmission projects would consequently need to be undertaken if SONGS were shut down. It found that Diablo Canyon, on the other hand, does not provide much in the way of grid reliability benefits. (CAISO 1999; CAISO 2000)

SCE has estimated the costs of transmission mitigation resulting from a shutdown of SONGS to be between $287 million and $673 million (2004$). (SCE 2004, p.5) Others have disputed this figure, arguing that some of the projects that SCE has proposed are unavoidable, even if SONGS continues to operate, and that SCE's modeling was flawed. (ORA 2004, p.8; SDG&E 2004, RS-1; Aglet 2004, p.6)

Atmospheric Emissions Benefits

Leading scientists across the country recognize the "greenhouse effect" – the existence of a heat-trapping layer of gases surrounding the earth. The overall warming that occurs when concentrations of GHG increase in the atmosphere is referred to as "climate change." While consensus has yet to be reached on the timing and magnitude, most scientists now agree that climate change is occurring, is caused by human activities, and could severely affect natural ecosystems and the world's economy.(Energy Commission 2005d) The National Academy of Sciences has reported that "abrupt climate changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies." They have predicted that most of the climate changes over the next century will be in response to human activities, such as the production of greenhouse gases and aerosols, and that these human activities may also increase the possibility of "large, abrupt, and unwelcome regional or global climatic events." (NAS 2002; NAS 2003)

Fossil-fueled power plants emit carbon dioxide and other pollutants as a byproduct of combustion. Other emissions from fossil fuel combustion, such as nitrogen oxides and particulates, result in environmental degradation, health problems, and other damage to society. In contrast, nuclear power plants emit very few greenhouse gases and other pollutants. Thus, nuclear generation results in a net reduction of air emissions compared to a scenario in which existing nuclear generation was replaced by either existing or new fossil-fired generation. The annual emissions savings from California's Diablo Canyon and SONGS is estimated to be approximately $130 to $360 million, depending on the technologies that the nuclear generation is replacing.

Fuel Diversity

California's power plants use a relatively diverse fuel mix. This diversity provides California with a partial hedge against dramatic price increases for any one particular fuel source. However, recent generation additions have been dominated by gas-fired generators, which currently account for over 40% of the state's power production. As new gas-fired generation comes online, it is expected that natural gas usage in the state will continue to increase relative to other fuel sources. Moreover, should California's nuclear power plants cease operations, much of the new generation sources that would replace them could be expected to use natural gas. Thus, nuclear power provides a significant fuel diversity benefit to customers as a hedge against natural gas price increases.

The use of nuclear power also helps to reduce the cost of natural gas by reducing demand for the product. Estimates of the annual natural gas cost increase that would result from the shutdown of Diablo Canyon and SONGS range from $226-$481 million statewide (Energy Commission 2005c; SCE 2004, Chapter V workpapers p.624) and $218-$581 million nationwide. (LBNL 2005) The use of renewable power, increased conservation, or power fueled by sources other than natural gas would reduce this impact.

Costs of California's Nuclear Power Plants

The costs to maintain California's nuclear power plants include operating and maintenance costs, major capital projects, security and waste management costs, and the costs of coastal damage and insurance risk. Due to uncertainty over future fuel prices, regulatory requirements, capital costs, and repair needs, there are wide variations in the estimated levels of these costs. The estimates below attempt to bound these costs based largely on public information from the CPUC steam generator replacement proceeding.

Steam Generator Replacement

The projected costs to operate and maintain California's nuclear power plants depend in large part on whether or not their proposed steam generator replacement projects are approved. (The replacement of steam generators at the Palo Verde nuclear power has been completed.) These projects, which would cost on the order of $700-$800 million per plant, likely need to be completed if the plants are to continue operating through the remainder of their operating licenses. Each of the four units has four to eight steam generators, which use the heat from water circulated through the reactor to evaporate another stream of water into steam that runs the turbines. (CPUC 2005a, p.4) These steam generators were initially intended to last the lifetime of the plants, but they have degraded and need to be replaced.

PG&E's application for cost-recovery of the proposed steam generator replacement project at Diablo Canyon has been approved by the CPUC on an interim basis pending the approval of the project's environmental impact report, which will be decided in September 2005. The CPUC has authorized $706 -$815 million to replace Diablo Canyon's steam generators, with no after-the-fact reasonableness review if the project is completed for less than $706 million (unless the CPUC has reason to believe the costs to be unreasonable). (CPUC 2005a) SCE's application, with its request for $680 million of cost-recovery, is still under review. A decision is expected in that case also in September 2005. (SCE 2005b, p.19)

In both cases, intervenors have argued that the utilities have underestimated costs by not adequately taking into account unexpected outages and repairs, which they say are likely to be required in these aging plants, and the costs to comply with additional security requirements that are currently under NRC review. (TURN 2004b, p.24) Mothers for Peace and California Earth Corps have estimated that PG&E and SCE's security costs could increase by up to $1.4 billion over 15 years due to these additional security requirements. (MFP 2004c, p. 10 Table A, p.13 Table D; CA Earth Corps 2005)

In the SONGS case, intervenors have also questioned the cost-effectiveness and the urgency of the project. SDG&E, a co-owner of the plant, has elected to relinquish part and possibly all of its ownership in the plant in return for not participating in this project due to the risk of significant cost-overruns. (SDG&E 2005a, p.42) The Office of Ratepayer Advocates has determined that the cost of the project outweighs its benefits. It has recommended that SONGS be shut down when its steam generators fail and its power replaced by power imported from out of the state or from elsewhere within the state, including from combined cycle plants, renewables, and conservation. (ORA 2004, p.4)

Revenue Requirements

Revenue requirements represent the costs to the ratepayers. These costs include capital costs, O&M costs, taxes, depreciation, and the utilities' return on their investments. The following tables show estimates of the total revenue requirements from continuing to operate Diablo Canyon and SONGS from 2005 through the end of each unit's license or, in the scenario where the steam generator replacement (SGR) is not completed ("Without SGR"), until the unit's premature shutdown.

Table ES-1: Diablo Canyon Revenue Requirements
(millions)

	With SGR	Without SGR
PG&E	$5,730	$2,851
CPUC	$6,365	$2,883
Intervenors	$8,443	$4,349

Table ES-2: SONGS Revenue Requirements
(millions)

	With SGR	Without SGR
SCE	$7,355	$3,021
SDG&E	$11,675	$3,948
Intervenors	$14,951	$4,782

Other Costs

Not included in the revenue requirement estimates are sunk costs, such as the costs to build and decommission the plants, and costs that are likely but difficult to quantify, such as unanticipated capital expenses. Also not included are unlikely but potentially expensive events, such as accidents or security events.

Additional Considerations

There are additional issues relevant to the discussion of the future of nuclear power in California that do not clearly enter the costs and benefits analysis. Some of these are national issues. Examples of additional considerations include the following:

- The Price-Anderson Act, which limits the liability of nuclear power operators in the event of an accident, has expired. Current plants are covered but any newly built plants will not be covered unless this act is extended.
- The Terrorism Risk Insurance Act, which guarantees insurance companies federal funds to cover 90% of above-deductible costs related to terrorist attacks, is set to expire at the end of this year.
- The nuclear insurance industry is set up using mutual insurance, which makes all owners of nuclear power plants liable to contribute funds in the event of an accident at any U.S. plant.

There are additional issues that pertain specifically to California's plants and their location along the seismically-active coast.

- The use of the ocean for cooling water has been found to have significant deleterious effects on the marine environment. (Energy Commission 2005b, p.93)
- The County of San Luis Obispo has raised concerns that Diablo Canyon's seismic plan is insufficient. The NRC has sole jurisdiction over seismic issues for the plants. (CPUC 2005a, p. 21)

- PG&E is currently studying the effects of a worst-case tsunami on Diablo Canyon and Humboldt Bay. SCE is confident of the safety of SONGS and has no plans for a new study. (Chronicle 2005)

Waste Storage and Disposal Issues

The federal government bears the responsibility to provide for the permanent disposal of high-level radioactive waste and spent nuclear fuel at the expense of generators and owners of the waste. Under the provisions of the federal Nuclear Waste Policy Act (NWPA), utilities remit regular fees to the Nuclear Waste Fund to pay for siting, constructing, and managing a federal waste repository. (42 USC, 111(a)) A permanent repository was to have begun accepting waste by January 31, 1998. The development of a permanent high-level radioactive waste disposal repository remains stalled. As a result, many of the nation's nuclear-owning utilities have constructed interim storage facilities on the sites of nuclear reactors.

Status of Yucca Mountain Waste Repository

In 1987, Congress amended the NWPA to limit future efforts for the development of a suitable repository site to Yucca Mountain in Nye County, Nevada. The Yucca Mountain site is considered attractive for several reasons. The site is remotely located in a sparsely populated area. Yucca Mountain has an arid climate, a deep groundwater table, and is located in an isolated hydrologic basin. Finally, the Department of Energy (DOE) has judged seismicity levels to be acceptable and considers the probability of volcanic activity to be low. (DOE 2002b) However, critics of the site note concerns about the high permeability of the rocks at the site, the rapid movement of surface water through rock formations, that the U.S. Geological Survey classifies the area as high risk for earthquakes, and the high likelihood of renewed volcanic activity over the 10,000-year life of the facility.

DOE estimates the total cost of constructing the repository at between $42.8 and $57.3 billion. These cost estimates are based on $4.3 billion in waste acceptance costs and the balance for construction and operation of the repository. If Yucca Mountain is not constructed, and DOE is required to manage the 70,000 MTHM of spent nuclear fuel at their present locations, estimated costs over the first 300 years are between $167 billion and $184 billion.

DOE is the federal agency charged with assessing the suitability of Yucca Mountain as a site for a permanent repository and then filing a license application with the NRC. The U.S. Court of Appeals upheld the State of Nevada's challenge to the radiation protection standard set by the Environmental Protection Agency (EPA). As a result, DOE must demonstrate the repository's ability to remain within a maximum radiation dose limit through the period of peak exposure to the environment. A revised EPA standard reflecting the court's ruling will be used as a basis for DOE's environmental impact analysis.

Significant and persistent concerns over quality assurance issues related to technical studies of the site during DOE's evaluation of Yucca Mountain have delayed DOE's readiness to file an application with the NRC. These concerns, which led to a suspension of site characterization work from 1989-1992, continue to surface. (GAO 1988)

The Yucca Mountain waste repository has been staunchly opposed by Nevada officials. The State of Nevada has filed legal challenges in various venues, and the governor issued a veto of the presidential recommendation that the permanent repository be located at Yucca Mountain. Continued opposition by the State of Nevada and environmental groups is expected throughout the application process, and uncertainty remains over whether the project will ever be constructed. The current target date for the completion of the site is 2012; however, that date is considered optimistic. Regardless of when or if the Yucca Mountain repository is licensed, constructed, and becomes operational, the amount of spent nuclear fuel in the U.S. will exceed the 70,000 MTHM capacity of the repository within 30 years.

Dry Storage Facilities

In the absence of a federal repository, the adequacy of spent fuel storage capacity has become an issue at California's nuclear power plants. Because the spent fuel storage pools at Diablo Canyon and SONGS are nearing capacity, PG&E and SCE have both applied for and received NRC licenses to construct on-site dry storage facilities known as independent spent fuel storage installations (ISFSIs).[1]

Dry storage of spent fuel is a relatively recent development. The first dry storage installation in the U.S. was licensed by the NRC in 1986 at the Surry Nuclear Power Plant in Virginia. As of December 2004, there were 32 dry storage installations at 25 active power plants and at seven additional plants that are decommissioned or in the process of decommissioning. (NRC 2004a)

Dry storage facilities are generally judged to be a cost-effective interim storage solution and, when designed and fabricated correctly, a safe method of storing spent nuclear fuel. Upfront costs related to licensing of the facility, initial construction of the pad or vault, and the purchase of the casks account for the majority of costs. Other costs are incurred for loading and sealing casks and monitoring and safeguarding the casks once they are placed on the storage pad. Assuming a dry storage facility is in place for 40 years, the life cycle costs are typically estimated at less than one-tenth of one cent per kWh generated. (Harvard 2001) The main safety considerations with a dry storage facility are that the cask design is sufficiently robust to withstand natural disasters, that it is loaded and sealed properly, and that venting not be obstructed. (Harvard 2001) Terrorism-related safety concerns for spent fuel storage have been raised since the September 11, 2001 attacks, but the NRC dismissed at least some of these concerns as being too speculative.

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[1] The Sacramento Municipal Utility District (SMUD) received a permit for constructing an ISFSI at the Rancho Seco nuclear power plant in order to reduce operating costs related to fuel storage. SMUD has moved all of the spent fuel into the ISFSI.

The NRC issues 20-year operating permits to approved dry storage facilities, subject to renewal, and has stated that dry storage is "safe and environmentally acceptable for a period of 100 years." (10 CFR 51 1989) It is uncertain how long the fuel will remain in these storage facilities. A federal repository is not expected to be available for at least 10-15 years and possibly much longer and it will take about 50 years to incorporate all of the spent fuel accumulating at all U.S. nuclear power plants into the repository once it becomes available.

Diablo Canyon's ISFSI

PG&E received approval from the NRC in September 2003 for the construction and operation of an ISFSI to store spent fuel from the Diablo Canyon plant. The proposed facility would be constructed in stages over the next 35 years at a cost of about $250 million (2001 dollars) and will have a capacity to store 4,400 spent fuel assemblies. (PG&E 2002) This would be sufficient to store all of the spent fuel accumulated through the end of Diablo Canyon's operating license. Several legal challenges to the NRC's approval of the ISFSI have delayed the construction of the ISFSI.

SONGS' ISFSI

SCE has already constructed and begun filling a dry cask storage facility with spent fuel from SONGS 1 and is in the process of licensing an additional facility for spent fuel from SONGS 2 and SONGS 3. SCE received permission from the California Coastal Commission for this additional ISFSI in 2001 and expects to receive NRC approval in July 2005. The facility will consist of 75 modules built in three phases through 2015 for a total cost of about $162.7 million. (CCC 2001a; SCE 2005a)

Other Waste Storage Options

Several other waste storage options have been investigated, primarily as interim storage options until a federal repository is prepared. Three alternative options are monitored retrievable storage, privately owned and operated storage facilities, and reprocessing.

Monitored Retrievable Storage

The concept of a monitored retrievable storage (MRS) facility is to be able to safely store spent fuel for as long as necessary while also providing for the ready retrieval of the spent fuel and waste for further processing or disposal. The development of an MRS facility in the U.S. was banned by Congress in 1987 out of concern that such a facility would become a de facto permanent repository. Between 1995 and 2000 occasional legislative efforts sought to locate an interim storage facility near the proposed geologic repository at Yucca Mountain, but none of these legislative efforts were successful. (Harvard 2001)

Private Spent Fuel Storage Facilities

In the early 1990s, a consortium of eight utilities formed an independent company called Private Fuel Storage, LLC (PFS) to develop a private interim spent fuel storage facility. (Harvard 2001) The consortium selected a site on the Skull Valley Indian Reservation in Utah and, despite fierce opposition from the state of Utah, applied for an NRC license.

The proposed facility would receive 50 shipments per year with an average of 3 to 4 casks per shipment. At this rate, the facility's 4,000 cask capacity would be expended in approximately 20 years. (WIEB 2005)

Another private company, the NEW Corporation, has proposed building a spent fuel storage facility in Owl Creek, Wyoming. This project is subject to Wyoming laws that prevent the submission of required analyses for legislative approval prior to DOE's application for a license to build a federal repository. Consequently, the Owl Creek Project would begin operating only a few years before a federal repository could begin accepting waste, reducing the value of such a facility. (Harvard 2001)

Reprocessing

During the 1960s and 1970s, the United States, along with the other nuclear-possessing countries, focused on the development of breeder reactors to reprocess spent fuel into plutonium and uranium, which could, in theory, be recycled into new fuel rods. (Von Hippel 2001) Reprocessing is the recovery of usable plutonium and uranium from fissile waste products.

Breeder reactors turned out to be technically more difficult to design and operate and more expensive than anticipated. In addition, the price of uranium dropped significantly after the discovery of more uranium deposits. The accident frequency at reprocessing plants throughout the world has been much higher than the accident frequency at reactors, (MIT 2003) and the reprocessing operation releases "small" amounts of radioactivity into the atmosphere or into liquid wastes from the reprocessing plant. These factors combined with the high cost of reprocessing and significant concerns over nuclear weapons proliferation effectively derailed the development of a reprocessing industry in the United States.

More recently the Bush Administration has reopened the debate over reprocessing spent fuel suggesting that reprocessing could reduce the country's nuclear waste stream and also enhance proliferation resistance. A recent MIT study found that reprocessing remains uneconomic in the U.S. today and will likely remain so until uranium becomes very scarce, which is not expected to happen for at least 50 years and possibly considerably longer.

Spent Fuel Transport Issues

Less radioactive materials such as low-level waste, medical isotopes, and industrial gauges are routinely shipped in the U.S. Spent nuclear fuel shipments occur much less frequently. About 2,500 MTHM of spent fuel were transported over the last 40 years. However, if a federal repository or repositories are approved, approximately 100,000 MTHM of spent fuel will need to be transported over about 38 years.

The transport of spent nuclear fuel is controversial due to safety and security concerns. The record so far provides some reassurance: of the 1,300 shipments of spent fuel in the United States since 1979, only eight resulted in reported accidents, none of which damaged the fuel casks, compromised the shielding, or caused any release of radioactive material. (NRC 2000) However, concerns remain about the vulnerability of spent fuel casks to terrorist attacks and the large increase in the projected volume and number of spent fuel shipments. The State of Nevada filed a petition in 1999 requesting a comprehensive reexamination of the consequences of radiological sabotage. The NRC accepted public comments on Nevada's petition but has yet to officially respond. (Nevada v. DOE 2005)

Radioactive materials transport is regulated jointly by federal and state governments. The sometimes conflicting or overlapping roles of state and federal agencies, combined with the uncertainty over the ultimate destination for nuclear waste materials, can lead to delays or inconsistencies in the regulation of nuclear waste transport.

Federal regulations include packaging and routing regulations, incident reports, carrier responsibilities, container manufacturer responsibilities, and security precautions throughout the transport. States are entitled to impose their own regulations, as long as they are not substantially different from federal regulations and do not unreasonably burden commerce. States may also pass laws that address areas not covered under federal regulations, and they retain the authority to determine driver qualifications, ensure safe operation of motor vehicles and conduct inspection and enforcement activities. (Smith 2004) They may also designate and enforce hazardous materials highway routes and impose transport fees. California's fees are currently lower than in most other states that have adopted fees.

The routes ultimately selected for shipments of spent fuel to a federal repository are a concern for California. DOE estimates that over 5,000 truck shipments or 375 rail shipments of other states' spent fuel could be transported through the state. (DOE 2002c) The number of shipments through California could be much higher, however, with one estimate ranging from 6,867 to 48,374 truck shipments or 660 to 9,643 rail shipments. (Halstead 2005a) DOE's preferred shipping method is by rail. The use of rail limits the number of spent fuel shipments, but it raises additional concerns in that no routing regulations exist for railroads. (Smith 2004) In addition, California has raised concerns about the increasing frequency with which federal nuclear waste shipments are re-routed through the state to avoid shipment through Las Vegas.

Long-Term Future for Nuclear Power in California

Recent developments both domestically and abroad suggest that a revival is taking place in the nuclear power industry. Concerns over climate change and increases in natural gas prices are among the drivers of this policy shift. The federal government has lent support to this effort with a government-industry cost-sharing program aimed at deploying new nuclear power plants by 2010. The National Commission on Energy Policy (NCEP), a nongovernmental, bipartisan group, has identified four potential benefits and four challenges to this expansion of domestic nuclear power use.

NCEP identified both environmental and economic benefits of nuclear power. The environmental benefits arise from the low greenhouse gas (GHG) emissions from nuclear reactors. This is an important benefit to California, which has as a goal to reduce GHG emissions to 2000 levels by 2010 and 1990 levels by 2020, and to reduce GHG emissions to 80% below 1990 levels by 2050. The economic benefits of nuclear power arise from nuclear power's relative reliability and from its use of uranium as a fuel rather than natural gas. Uranium is less expensive and more abundant than natural gas, providing a more stable power price. Moreover, insofar as uranium replaces natural gas, which is the marginal fuel in California, it also mitigates natural gas supply pressures and potential price increases.

Two challenges to nuclear power expansion are cost and safety. The cost-effectiveness of nuclear power may improve in future years. A 2003 MIT study found that with high gas prices, a carbon tax, and some plausible cost reductions, nuclear power could become competitive with coal and natural gas. (MIT 2003) Safety challenges include the threats of terrorist attacks, plant malfunctions or human error leading to a power plant accident, and containing nuclear proliferation. Another major concern is the disposal of spent fuel.

NCEP also identified strategies to address these challenges. To address cost concerns, it recommended the use of standardized reactor designs, the granting of federal support to develop advanced technologies, and the inclusion of nuclear energy in renewable portfolio standards. To address safety concerns, it recommended the expansion of the NRC's licensing process to consider a plant's ability to resist a terrorist attack. It also recommended that the government license Yucca Mountain as a spent fuel repository and construct dry-cask spent-fuel-storage facilities at multiple locations throughout the U.S. Finally, to address proliferation concerns it recommended that the current moratoria on commercial reprocessing of spent nuclear fuel and construction of commercial breeder reactors be continued, that the federal government support the development of advanced technologies that could reduce spent fuel and make the diversion of weapons-grade material more difficult, and that the government work with other countries and agencies to prevent the proliferation of nuclear material globally.

Conclusions and Recommendations

Following are preliminary conclusions and recommendations that arise from this report. These are to be considered alongside reviewers' comments on this report and the record developed during two days of panel discussions by a variety of experts and advocates.

New Nuclear Power Plants in California

The Energy Commission will likely not receive any applications to construct new nuclear power plants in California in the near future. Moreover, as the nuclear waste disposal issue remains unresolved, the Energy Commission could not approve such applications at this time.

Spent Fuel Reprocessing and Implications for California

Reprocessing remains substantially more expensive than waste storage and disposal, and it still has substantial implications for U.S. efforts to halt the proliferation of nuclear weapons material and technology.

Waste Storage and Disposal and Implications for California

At this time the Energy Commission cannot conclude that DOE will ever license and operate the permanent repository at Yucca Mountain. DOE's failure to license and operate a permanent repository has imposed substantial costs on California's consumers who have paid over a billion dollars for this service and have had to incur the costs of building and operating interim fuel storage facilities.

Consequences of Failure to Develop Yucca Mountain

California needs a comprehensive assessment of the implications of indefinitely relying on interim fuel storage facilities. For example, the California Attorney General has participated in a court challenge requesting that the NRC consider the implications of terrorist acts in its environmental review of the proposed ISFSI at Diablo Canyon. The State should also consider other means to insure a study of the potential implications of terrorism is performed, such as a request to the Department of Homeland Security or the U.S. Government Accountability Office.

Since the interim fuel storage facilities will likely be relied upon for decades, the State should assess whether any adjustments to the existing nuclear power plant decommissioning plans are needed. This assessment should include the decommissioning plans for the interim fuel storage facilities.

Transportation Issues

California should perform a comprehensive assessment of its likely costs associated with the transport of spent fuel within and through California to insure that its fees are reasonable and adequate to cover costs.

The Energy Commission should continue its participation in collaborative processes at the national and regional level to ensure that the State's interests are represented in the transport of nuclear material through the State.

The Energy Commission should also continue to coordinate the California Interagency Transport Working Group to plan, prepare and initiate state needs assessments for spent fuel and other large radioactive shipments in California.

Costs and Benefits of the Existing Nuclear Power Plants

The direct benefit of energy and capacity from Diablo Canyon and SONGS, as measured by the cost of replacement power, is on the order of $1.5 billion to $2.5 billion per year.

The indirect benefits of reduced demand for natural gas are likely to range between $218 million to $581 million per year.

The social benefits of reduced air emissions including greenhouse gas emissions are likely to range between $67 million and $678 million per year.

Shutting down SONGS could require significant investments in transmission upgrades or replacement generation capacity to maintain the reliability of the grid in southern California. The potential range of these investments has been estimated by SCE as $287 million to $673 million.

Estimated revenue requirements for continued operation of these facilities through the end of each unit's license range from $6 to $10 billion for Diablo Canyon and from $7 to $16 billion for SONGS.[2]

The State should ask PG&E, SCE, and SDG&E to describe their backup plans for the power from the existing nuclear reactors in the event that any of these facilities undergo extended outages.

Potential Expansion of Nuclear Power

Nuclear energy technology research and development has continued to evolve since the current fleet of nuclear power plants was designed and built in California. Even with a virtual moratorium on new orders of nuclear power plants in the U.S., construction has continued internationally, particularly in Asia.

California should monitor the status of DOE's efforts to develop new nuclear technologies, including the estimated life-cycle costs and performance of advanced reactors.

[2] The high end of this range includes $1.4 billion in potential additional security costs.

CHAPTER 1: INTRODUCTION

Background

A substantial share of California's electricity supply is produced by combusting fossil fuels such as natural gas and coal. Although fossil fuel combustion is the engine of our modern way of life, it poses trade-offs and challenges. Fossil fuel supplies are finite and are being rapidly depleted. In addition, fossil fuel combustion emits greenhouse gases and various air pollutants. Natural gas is less polluting than coal, but California produces only 15% of the natural gas it consumes and the remainder comes from other states and countries. This has certain geopolitical and economic implications. Because California's power system is heavily reliant upon natural gas, in the future the state may require new sources of natural gas such as liquefied natural gas or synthetic natural gas to fuel its power plants. Given these considerations, California has opted in recent years to give priority to energy efficiency and renewable energy.

Since the 1970s, nuclear power has not been viewed as a fuel of choice for providing electricity in California. Among other reasons, the financial burden of substantial construction cost overruns for building nuclear power plants caused a loss of support for nuclear power in the 1970s and 1980s. In 1976 California passed legislation that prohibits the construction of any new nuclear power plants in California until the California Energy Commission (Energy Commission) finds that the federal government has demonstrated and approved a technology for the permanent disposal of spent fuel from these facilities, effectively placing a moratorium on the development of nuclear power in California.

Nevertheless, nuclear power provides a sizable share of the electricity consumed every day in California. The state's nuclear power plants are aging, however, and face the expiration of their operating licenses in the 2020s. For this reason alone, California's policymakers need to begin the discussion of what role nuclear power should play in meeting the state's electricity needs.

Other developments also suggest the time is ripe for California to undertake a coordinated and comprehensive review of nuclear power issues. Climate change is a challenge that must be addressed; should a non-carbon fuel source such as nuclear power be part of the solution? Do terrorist or other security threats outweigh any possible benefits of nuclear power? Existing state legislation prohibits new nuclear plant construction until waste disposal issues are resolved; have those issues been adequately addressed since the passage of the nuclear laws in the 1970s?

Objectives

The specific objectives for this report were to provide an assessment of a broad range of issues related to the continued operation of nuclear power plants within the state. The issues addressed in this report include the role of nuclear power in the state's electricity supply portfolio, the state's responsibilities under California's nuclear legislation, the current status of nuclear waste disposal, proliferation and terrorism threats, and the benefits and vulnerabilities of an expanded or long-term reliance on nuclear technology. The report also outlines an inventory of the potential costs and benefits associated with California's continued reliance on aging nuclear power plants. The information provided in this report is intended to inform the broader efforts of the Energy Commission's 2005 *Integrated Energy Policy Report* (Energy Report).

Methods

The information presented in this report is based largely on the research and studies of many other organizations, the federal government, and universities. Much of the California-specific information was drawn from regulatory filings and regulatory agency reports. Personal communications between the report's authors and knowledgeable experts in the nuclear industry add to the currency of the report.

The IEPR Committee will conduct a two-day workshop on August 15 and 16 to review the status of California's currently operating nuclear power plants, the status of federal programs to manage and permanently dispose of spent fuel from these plants or to reprocess spent fuel, and the potential role of nuclear power in California's energy future. Four panels of experts have been assembled for this workshop. MRW & Associates, Inc. will also provide a brief presentation of the findings of this white paper. The Committee encourages interested parties to submit written comments on this white paper in advance of the workshop, but no later than 5 p.m. on August 23, 2005. Information discussed at the workshop and all written comments will be considered in the development of the Energy Report.

Report Structure

The remainder of this report is structured as follows:

- Chapter 2 provides an overview of current issues associated with nuclear power in California.
- Chapter 3 provides an inventory of the expected "going-forward" costs and benefits of operating California's existing nuclear plants until the current operating licenses expire in the decade of the 2020s.
- Chapter 4 examines options for storing, disposing of or reprocessing spent nuclear fuel.
- Chapter 5 reviews the implications of transporting spent fuel from existing sites either to Yucca Mountain or a centralized interim storage facility.
- Chapter 6 identifies a number of issues driving a potential revival of nuclear power and efforts to end the current nuclear power policy stalemate.
- Chapter 7 provides a brief discussion of some preliminary findings from this study.

CHAPTER 2: NUCLEAR POWER IN CALIFORNIA

Electricity generated by nuclear power plants first flowed into California's electricity grid nearly fifty years ago. Today California relies on three nuclear power plants located at Diablo Canyon, San Onofre and Palo Verde for a sizable share of the state's overall electricity supply. All three of these nuclear power plants, which began commercial operation in the mid-1980s, have been operating for about 20 years and are licensed to continue operating for roughly another twenty years.

Because of California's dependence on nuclear power for a significant portion of its electric generating capacity, policymakers and other vested stakeholders need to consider issues central to the operation and safety of the state's nuclear power plants as well as related issues such as the storage and disposal of nuclear waste and the environmental costs and benefits of this non-carbon fuel source.

Historical Policy Issues

When California evaluated the implications of nuclear power in the 1970s, the public debate generally centered on the following issues:

- How much energy did California require to maintain its life style and grow its economy?
- How much of that energy should be supplied by electricity?
- How much of that electricity should be supplied by nuclear power?
- What were the costs and benefits of nuclear power plants?
- California's utilities wanted to construct the nuclear power plants along the coast to utilize ocean water for cooling the reactors. Should California's magnificent coast be home to nuclear power plants, reserved as valuable recreation land, or used in some other fashion?
- Much of California's coastline is seismically active. Could acceptable coastal sites be located? Could the facilities be designed to meet appropriate seismic standards?
- Considering the consequences of both routine emissions and reactor accidents, were the risks of nuclear power acceptable?
- Finally, was there an acceptable waste disposal solution for the spent fuel and high level nuclear wastes that were a natural byproduct of the generation of nuclear power? (Wellock 1998)

Some of these questions persist today.

For a variety of reasons the 1970s and early 1980s witnessed both a significant drop in the expected need for electricity in California and also an unprecedented jump in the installed costs of nuclear power plants. In 1975 a report prepared for the California legislature by the Rand Corporation forecast that California would need between 392 to 625 billion kWh by 2000. The same report also predicted that California's electricity resource supply mix would include 17,966 MW of nuclear power to provide about 102 billion of those kWh (Ahern 1975, p.144). California actually used 263 billion kWh in 2000 (Energy Commission 2002a) which included about 44 billion kWh (Energy Commission 2003) from about 5,500 MW of nuclear power plants. Similarly, the initial projected construction costs of the Diablo Canyon nuclear power plant and the San Onofre plant were $320 million and $436 million, respectively. The actual final construction costs of Diablo Canyon and San Onofre were $5.66 billion and $4.51 billion, respectively, or an increase of about 20 and 10, respectively.(CA Senate 1987, p.13; Dunstan 2002, p.37)

California's Nuclear Power Plants

At the present time, there are three operating nuclear power plants supplying power to California: Diablo Canyon Units 1 and 2, the San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 (both in California), and the Palo Verde nuclear power plant Units 1, 2, and 3 (in Arizona). In addition, there are three retired nuclear power plants in California: Humboldt Bay, Rancho Seco and SONGS Unit 1. Figure 1 shows the locations of these plants.

Figure 1: Map of California Nuclear Power Plants

Source: (USDOE 2005)

Operating Plants

California's utilities have ownership rights to three operating nuclear power plants. These are:

- The Diablo Canyon Power Plant. The Diablo Canyon facility is located near San Luis Obispo. PG&E owns and operates Diablo Canyon, which has a total generating capacity of 2,220 MW.

- The San Onofre Nuclear Generating Station. SCE and SDG&E are co-owners of the San Onofre Nuclear Generating Station (SONGS), which has an overall capacity of 2,254 MW. SONGS is located near the boundary between the SCE and SDG&E systems near San Clemente, California. The SONGS plant has three units, one of which is now retired.

- The Palo Verde Nuclear Generating Station. Palo Verde has an overall capacity of 3,810 MW and is located near Phoenix in Wintersburg, Arizona. It is operated by the Arizona Public Service Corporation. Palo Verde consists of three units. California utility ownership of Palo Verde corresponds to a total of 27% in the Palo Verde nuclear power plant. Palo Verde is among the largest power plants in the United States.

Table 1 provides additional information about these three power plants.

Table 1: California's Operating Nuclear Power Plants

Nuclear Plant	Unit	Size	Operator	Ownership	Date Began Commercial Operation	Expiration of Current License
Diablo Canyon	Unit 1	1087 MW	Pacific Gas and Electric	Pacific Gas and Electric	May 7, 1985	Sept 22, 2021
	Unit 2	1087 MW			Mar 15, 1986	Apr 26, 2025
SONGS	Unit 2	1070 MW	Southern California Edison	Edison International (75.1%), SDG&E (20%), Anaheim Public Utilities Department (3.2%), Riverside Utilities Department (1.8%)	Aug 8, 1983	Feb 16, 2022
	Unit 3	1080 MW			Apr 1, 1984	Nov 15, 2022
Palo Verde	Unit 1	1243 MW	Arizona Nuclear Power Project	SCE (15.8%), SCPPA (5.9%), LADWP (5.7%)	Jan 28, 1986	Dec 31, 2024
	Unit 2	1243 MW			Sep 19, 1986	Dec 9, 2025
	Unit 3	1247 MW			Jan 8, 1988	Mar 25, 2027

Retired Plants

California is also home to three commercial nuclear power plant units that are no longer in operation though spent fuel continues to be stored at each of the sites. These facilities are located at Humboldt, Rancho Seco and SONGS.

- PG&E operated the Humboldt Bay Nuclear Plant in Eureka from August 1963 to July 1976. A moderate earthquake caused damage to this 63 MW plant and it closed because the seismic retrofit was not economical. Humboldt's decommissioning will begin in 2006. (Energy Commission 2002b)

- The 913 MW Rancho Seco Nuclear Power Plant is located 25 miles south of Sacramento and is owned by the Sacramento Municipal Utility District. It was in operation from April 1975 to June 1989 when it closed by public referendum. Decommissioning has already begun at Rancho Seco. (Energy Commission 2002b)

- SONGS Unit 1 was a 436 MW reactor in operation from January 1968 to November 1992. Required modifications were not economical and therefore it was shut down. Decommissioning of SONGS Unit 1 began in 1999. (Energy Commission 2002b)

California's Experimental Reactors

Two small experimental reactors were built in California.

The Santa Susana Sodium Reactor Experiment, located in Ventura County, was a small sodium-cooled experimental reactor. It operated in from 1957 to 1964. This reactor used sodium rather than water as a coolant, and produced a maximum of 7.5 MW. In July 1959 Santa Susana suffered a partial meltdown and one third of its core melted. Another meltdown occurred in 1964 when 80% of the core melted. The plant was subsequently dismantled. (Energy Commission 2002b)

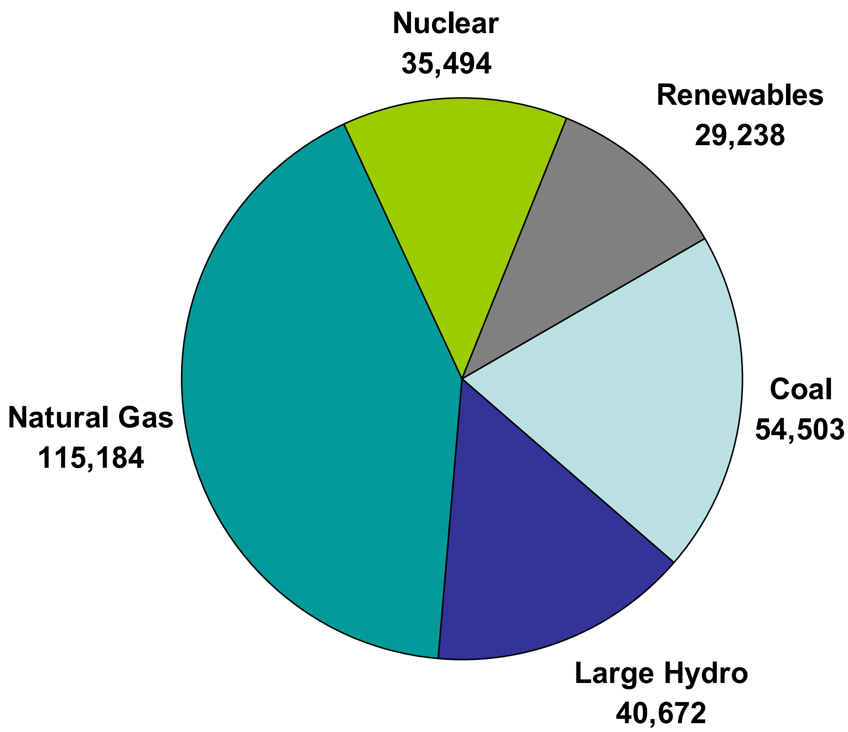
The Vallecitos Nuclear Power Plant near Pleasanton was jointly operated by PG&E and General Electric Company. Vallecitos, the first privately owned and operated nuclear plant to deliver significant quantities of electricity to the grid, was a small (5 MW) plant that operated from 1957 to 1963. The site received spent reactor fuel rods from other sites for research purposes. NRC reports that spent fuel has been removed from the site and a research reactor is still in operation. (NRC, p. A-17)

Contribution to California's Power Supply

The operating reactors at Diablo Canyon, SONGS and Palo Verde provide a combined capacity of 8,057 MW. In 2004 nuclear power made up 13% of California's electricity supply. By comparison, natural gas-fired power plants supplied 42% of the state's electricity supply and hydroelectric power accounted for 15% (see Figure 2). (Energy Commission 2005a)

Figure 2: California 2004 Gross System Power

(GWh)



Source: (Energy Commission 2005a)

Federal Regulatory Environment

Atomic Energy Act

The Atomic Energy Act of 1954 established the framework for commercial development of nuclear energy in the United States based on a policy of encouraging "widespread participation in the development and utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public." (42 USC, 2013(d)) The law established the Atomic Energy Commission (AEC) and charged that agency with the pursuit of research and development activities to promote atomic energy development.

The Atomic Energy Act also gave the federal government jurisdiction over the "possession, use and production of atomic energy and special nuclear material" (42 USC, 2013(c)) due to their impacts on interstate and foreign commerce, common defense and security, and the public good. The AEC was authorized to oversee these areas and to issue licenses that would be required to "transfer or receive in interstate commerce, manufacture, produce, transfer, acquire, own, possess, import, or export any [nuclear] byproduct material."(42 USC, 2111)

The AEC was authorized to partially transfer this jurisdiction to states with approved radiation standards in place. (42 USC, 2021(b)) States would be granted some authority to regulate certain nuclear materials in order to protect public safety. They would not be given authority over the construction and operation of nuclear power plants, exporting or importing of nuclear materials, or disposing of nuclear materials.[3] These areas were to remain under federal jurisdiction.

Energy Reorganization Act of 1974

The AEC's dual jurisdiction to both promote and regulate the nuclear power industry was perceived by many as a conflict of interest, with the AEC being seen as having a "heavy bias toward promoting nuclear power." (Wellock 1998) The Energy Reorganization Act of 1974 addressed this concern by replacing the AEC with two new agencies, the Energy Research and Development Administration (now the Department of Energy) and the Nuclear Regulatory Commission (NRC). The former was given responsibility over the research, development, and promotion of nuclear power and the NRC was given jurisdiction over the safety regulation of the civilian uses of nuclear materials. (42 USC, 5801)

The Energy Reorganization Act also established the Office of Nuclear Reactor Regulation within the NRC with primary responsibility over the licensing and inspections of nuclear facilities. This inspection program now includes full-time resident inspectors at each plant and regional inspectors with specialized expertise.(NEPDG 2001b, pp.1-7) Plant assessment programs evaluate safety and security standards at the plants, including "plant operations, radiological controls, maintenance, surveillance, emergency preparedness, and security." (CA Senate 1991)

Federal vs. State Jurisdictional Roles

The NRC regulates commercial nuclear power plants; research, test, and training reactors; nuclear fuel cycle facilities; medical, academic, and industrial uses of radioactive materials; and the packaging, storage and disposal of radioactive materials and waste. The Atomic Energy Act gave broad regulatory control to the NRC while also leaving some responsibility to the states. It distinguished between radiation hazards, which were to be regulated at the federal level, and other aspects of nuclear power, which were to remain under state jurisdiction.[4] PG&E tested the boundaries of these jurisdictions in a case that the Supreme Court decided in 1983. This case arose as a result of two California laws that restrict nuclear power development: Section 25524.2 of the California Public Resources code, which establishes a moratorium on new nuclear

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[3] This restriction was later limited to high-level nuclear materials.

[4] "Nothing in this section shall be construed to affect the authority of any State or local agency to regulate activities for purposes other than protection against ***radiation*** hazards." (42 USC)

facilities until a permanent waste disposal technology has been demonstrated and has been approved, and Section 25524.1(b), which restricts construction of nuclear facilities unless adequate capacity for interim spent fuel storage can be demonstrated. PG&E argued that both of these laws were preempted by the Atomic Energy Act, which granted jurisdiction over nuclear power plant development to the federal government.

The U.S. Supreme Court decided the case on April 20, 1983 (PG&E vs. Energy Commission 1983). The court ruled that “the Federal Government maintains complete control of the safety and ‘nuclear’ aspect of energy generation, whereas the States exercise their traditional authority over economic questions such as the need for additional generating capacity, the type of generating facilities to be licensed, land use, and ratemaking.” (PG&E vs. Energy Commission 1983) This ruling established that “actions of the states that are designed to regulate radiation hazards from such [nuclear power] facilities are preempted by federal law,” while state actions designed to regulate “environmental impacts not associated with radiation hazards and the economics of continued investment in and operation of those facilities” are authorized. (Chamberlain 1991)

The haziness of this boundary between federal and state jurisdictions is apparent in the regulation of nuclear waste transport. Two federal agencies, the NRC and the Department of Transportation, have primary responsibility for ensuring the safety of the preparation and transport of nuclear materials. However, states are given authority to impose additional regulations on nuclear waste transport as it relates to traffic safety. Moreover, many states have enacted additional regulations in areas that fall under federal jurisdiction. The courts have generally let stand state laws that do not conflict with federal laws or unreasonably burden interstate commerce. In certain cases, local laws that are more restrictive than federal laws are allowed, if local conditions mandate additional safety requirements. State laws that have been validated include rules regarding headlight illumination, accident reporting, driver training requirements, and vehicle inspections. State laws that have been invalidated include absolute shipment bans, curfews, burdensome permitting requirements, and rail shipment registration requirements.(Smith 2004)

State Regulatory Agencies

The primary state regulatory agencies that can impact nuclear power plants in California are the California Energy Commission, the regional water quality control boards, the California Coastal Commission (CCC), and the California Public Utilities Commission (CPUC). We will discuss each of these agencies in turn.

California Energy Commission

The Energy Commission, technically known as the California Energy Resources Conservation and Development Commission, was created by the 1974 Warren-Alquist Act (PRC, 25000) as the state’s primary energy research and planning agency. In most cases, it has responsibility for siting and licensing new thermal power plants of 50 MW or larger.[5] The power plant siting process has been certified under the California Environmental Quality Act (CEQA), which allows the Energy Commission to use the documents it develops in the licensing process as the "functional equivalent" of an environmental impact report. (Energy Commission 2000) As part of the licensing process, the Energy Commission must include "identification of the significant effects of a project on the environment, feasible mitigation measures, and alternatives to the project." (Energy Commission 2000)

Older plants issued a Certificate of Public Convenience and Necessity (CPCN) by the CPUC or approved by a municipal utility before January 7, 1975, including both Diablo Canyon and SONGS, are not subject to Energy Commission jurisdiction. (Energy Commission 2000; PRC, 25501) These plants are also exempt from California's nuclear laws ((PRC)22524.1(b), 22524.2). (Chamberlain 1991)

Nuclear plants are subject to the jurisdictional separation provided for in the Atomic Energy Act, as interpreted by the Supreme Court decision in PG&E v. Electric Resources Commission (described above). In general, states have jurisdiction over all non-radiation aspects of nuclear generation, such as the question of where to most economically site the plants, while the federal government has jurisdiction over radiation safety issues, such as those that arise in licensing cases. Some safety issues are also addressed within the siting cases, such as the prevention of illegal diversion of nuclear fuel and means to control the population density in areas surrounding a nuclear power plant. (PRC, 2551)

The Energy Commission also has the responsibility to prepare and adopt a biennial integrated energy policy report that contains "an overview of major energy trends and issues facing the state, including, but not limited to, supply, demand, pricing, reliability, efficiency, and impacts on public health and safety, the economy, resources, and the environment" and presents "policy recommendations based on an in-depth and integrated analysis of the most current and pressing energy issues facing the state."(SB 1389)

Regional Water Quality Control Boards

The State Water Resources Control Board and the regional water quality control boards are responsible for administering the National Pollution Discharge Elimination System (NPDES) program in California. Pursuant to this authority, the regional boards issue NPDES permits. These permits address impacts associated with the discharge of pollutants, thermal imports, and impacts due to the use of once-through cooling. Each permit has a term of five years and is renewable. In addition, the regional boards are responsible for implementing state water policies, one of which specifically addresses once-through cooling using ocean water, for example, in nuclear power plants. The EPA recently issued guidance for evaluating once-through cooling impacts associated with both existing and new cooling water intake structures. These regulations contain

[5] "The commission shall have the exclusive power to certify all sites and related facilities in the state, whether a new site and related facility or a change or addition to an existing facility." (PRC, 25500)

performance standards, monitoring requirements, and detailed data submission and review rules. There is currently litigation concerning both sets of regulations, and considerable uncertainty about how the rules will be implemented.

California Coastal Commission

The CCC is an independent state agency with the mission to “protect, conserve, restore, and enhance environmental and human-based resources of the California coast and ocean for environmentally sustainable and prudent use by current and future generations.” The CCC has jurisdiction over all development in a coastal zone, except for thermal energy plant siting, which is under the Energy Commission’s jurisdiction.[6] Even in this case, the CCC retains significant authority, as the Energy Commission is required to adopt provisions identified by the CCC as necessary to meet the objectives of the Coastal Act unless the Energy Commission finds that the provisions would result in greater adverse effect or would not be feasible.

The CCC or local agencies implementing approved local coastal programs may also have partial jurisdiction over other facilities located at a power plant site. These entities address conformity of proposed projects to applicable policies of the Coastal Act and do not evaluate or condition the proposed project with respect to nuclear safety or radiological issues. For instance, CCC permits are required for waste storage facilities that are located in a coastal zone and for non-radiation-related nuclear building construction and decommissioning activities that take place in a coastal zone. In evaluating permit applications, the CCC or local government considers non-radiation related impacts of these activities, such as the impacts of building or demolishing on biological resources, the demolition-related noise and light impacts on environmentally sensitive habitat areas, and the activities’ impacts on recreation, public access, and aesthetic values. Related permits, such as air quality and water discharge permits, may also be required by local environmental boards.

California Public Utilities Commission

The CPUC is a five-member gubernatorial-appointed constitutional body. The jurisdiction and responsibilities of the CPUC are described as follows:

> [The CPUC] has jurisdiction to set the rates, terms and conditions of service for the Utility's electricity distribution, natural gas distribution and natural gas transportation and storage services in California. The CPUC also has jurisdiction over the Utility's issuances of securities, dispositions of utility assets and facilities, energy purchases on behalf of the

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[6] Except as provided in subdivision (e), and in addition to obtaining any other permit required by law from any local government or from any state, regional, or local agency, any person, as defined in Section 21066, wishing to perform or undertake any development in the coastal zone, other than a facility subject to Section 25500 (i.e., a thermal energy plant), shall obtain a coastal development permit. (PRC 300600(a) 2005)

> Utility's electricity and natural gas retail customers, rate of return, rates of depreciation, aspects of the siting and operation of natural gas transportation assets, oversight of nuclear decommissioning and aspects of the siting of the electricity transmission system. . . . In addition, the CPUC conducts various reviews of utility performance and conducts investigations into various matters, such as deregulation, competition and the environment, in order to determine its future policies. (PG&E 2004e)

The CPUC has two general roles with regard to the state's nuclear power development. When a siting case for a project requiring a CPCN is open before the Energy Commission, the Energy Commission seeks recommendations from the CPUC "regarding the design, operation, and location of the facilities designated in the notice in relation to the economic, financial, rate, system reliability, and service implications of the proposed facilities."(PRC, 25506.5) Subsequently, once a plant has been licensed and sited, the CPUC has the responsibility to determine how its costs should be allocated among ratepayers and shareholders. The CPUC determines revenue requirements for plant construction, plant operation, and major capital projects to be done at the plants such as the steam generator replacement projects for Diablo Canyon and SONGS. For example, the CPUC has been evaluating the reasonableness of the proposed steam generator replacement projects and is the lead agency for the CEQA review of these decisions. The CPUC also holds a triennial nuclear decommissioning proceeding for each utility to determine the annual revenue required for each plant's decommissioning trust fund.

California's Nuclear Laws

California law prohibits the construction of any new nuclear power plants in California until the Energy Commission finds that the federal government has demonstrated, and the U.S. authorized agency has approved, and there exists a technology for the permanent disposal of spent fuel from these facilities. Specifically, in June 1976, California enacted legislation directing the Energy Commission to perform an independent investigation of the nuclear fuel cycle. This investigation sought to determine whether the technology to reprocess nuclear fuel rods and/or to dispose of high-level nuclear waste had been demonstrated, approved and was operational. (See PRC 25524.1 (a) (1), 25524.1 (b), and 25524.2 (a) for the specific findings and conclusions). After extensive public hearings, the Energy Commission determined that neither technology met the required standard. (Energy Commission 1978)

Nuclear Policy Issues Facing California

Determining the appropriate role for nuclear power in meeting California's electricity needs requires weighing many conflicting policy priorities and making difficult trade-offs.

- California's existing nuclear power plants deliver non-carbon based power into the California grid with relatively low operating costs and on a reliable basis. California's ratepayers have paid down the substantial initial capital investment and ongoing capital additions for these plants. On the other hand, continued operation of these plants will require significant additional investments in the next five years to replace the steam generators and other major equipment, to build onsite waste storage facilities, and to train and replace existing workforces. Before making these commitments, a review of the likely “going-forward” costs and benefits of these facilities is necessary.

- Since September 11, 2001, concerns about the potential consequences of accidents or human error at nuclear power plants have been joined by security concerns, which have been a controversial topic at the national level.

- Nuclear waste disposal remains one of the most important issues to be resolved for an expansion of nuclear power. As a consequence of the failure of federal efforts to license and operate a permanent waste repository at Yucca Mountain, the existing reactors have become the sites of interim waste storage facilities. These interim waste storage facilities may be required to operate for decades after the plants are shut down.

This section lays out a number of issues that policymakers face today and will face in the coming years as they make critical choices for California’s energy policy.

Contribution to Electricity Supply

Policy makers must consider a number of questions concerning the present and future contribution of nuclear power plants to California’s electricity supply, including:

- How much of California’s electricity requirement will be provided by the existing nuclear power plants at Diablo Canyon, SONGS, and Palo Verde throughout the period of this IEPR, which covers through 2016?

- What are the direct benefits of energy and capacity from these resources?

- Is there locational value of power produced at these three locations? For example, what would be the costs of any additional transmission or generation facilities required to replace the output from these units?

- How uncertain are these likely benefits – what is the likely range?

- What are the likely actions that will be required to preserve the output of these plants, such as steam generator replacement, replacement of other major pieces of equipment, security upgrades, recruiting and training replacement workforces, building and operating interim spent fuel storage facilities, contracting for fuel supplies, etc.?

- What are the likely costs of these actions?

- How uncertain are these likely costs – what is the likely range?

- While these nuclear facilities do not produce significant direct air emissions or emissions of greenhouse gases, Diablo Canyon and SONGS do require substantial amounts of ocean cooling water and discharge substantial quantities of heat into the coastal waters. What are the environmental consequences of these intakes and discharges of coastal water? How successful have the operators been in mitigating these impacts? What are the likely costs and benefits of future mitigation efforts?

- What are the backstop resources for these facilities, considering their size and locations?

Waste Storage and Disposal

Operation of nuclear power plants generates spent nuclear fuel. The lack of progress at the federal level toward developing and operating a permanent nuclear waste repository remains one of the most significant challenges facing the nuclear power industry today. Given this, policymakers should consider the following questions:

- What is the current status of the Department of Energy's (DOE) efforts to license and operate the permanent waste repository at Yucca Mountain? What are the implications of the need for a second repository?

- When can California plan on the operation of a permanent waste repository at Yucca Mountain, if ever?

- Spent fuel pools have been re-racked to denser and denser configurations at SONGS, Diablo Canyon, and Palo Verde. Given its difficulties in licensing and constructing an interim fuel storage facility at Diablo Canyon, PG&E has proposed additional re-racking of its spent fuel pools. What are the implications of this proposal?

- Interim fuel storage facilities with dry casks have been or will be constructed at Humboldt Bay, Diablo Canyon, Rancho Seco, and SONGS. The California Attorney General, Mothers for Peace, and others have challenged the NRC decision concerning PG&E's application for a license to construct and operate an interim fuel storage facility at Diablo Canyon due to the NRC's refusal to consider the implications of terrorism in its NEPA assessment of this application. This challenge is pending at the Ninth Circuit Court of Appeals. What are the implications of these interim fuel storage facilities for Californians?

- PG&E has recently announced that it has initiated a study to assess how Diablo Canyon and Humboldt Bay would be affected by worst-case scenario tsunamis, reflecting the implications of the December 2004 Sumatra tsunami event. SCE has no plans for such a study. What might be the implications for California of such a worst-case scenario?

- In the heightened security environment after September 11, 2001, increased attention has been paid to the vulnerability of nuclear facilities to acts of terrorism.

Nuclear power plants should be well-protected due to their substantial containment vessels, but spent fuel pools and interim fuel storage facilities may be more vulnerable. There has been a vigorous debate among the NRC, the National Academy of Science and the GAO on this topic. What are the consequences for California of conclusions and recommendations related to nuclear plant security?

- The interim fuel storage facilities located at California reactor sites are designed to accommodate not only the current inventory of spent fuel, but also the spent fuel likely to be produced over the remainder of the plant operating licenses. PG&E's project description characterizes the facility as one that will be in place for twenty to forty years, but also recognizes that it may be in place for a longer period. What are the long-term implications for California of reliance on these facilities over such a long term? For example, are there any implications for the decommissioning plans for nuclear power plants?

- Reprocessing could be used to recycle spent fuel and to compact the unused spent fuel. However, reprocessing is more expensive than direct disposal of spent fuel, it produces a high-level nuclear waste stream, and it may pose an increased risk of proliferation of nuclear weapons. Reprocessing of spent fuel would also represent a significant change in long-standing U.S. policy. Should California continue to ignore the reprocessing option?

- Spent fuel could also be stored at a centralized interim fuel storage facility located somewhere in the West until a permanent repository at Yucca Mountain becomes operational. What are the tradeoffs between interim storage facilities located at the various nuclear power plants versus at a centralized facility? How likely is the successful construction and operation of such a centralized facility? Can California periodically assess such a facility?

- How would spent fuel be transported from the California fuel storage facilities to either a centralized interim fuel storage facility (and then to the permanent repository) or to a permanent repository at Yucca Mountain? What are the transportation implications for California of decisions on alternate routes and shipment modes? The NRC regulates the radiological aspects of transporting such spent fuel, but the state continues to play a significant role in waste transportation. What are the trade-offs between continuing interim fuel storage at the power plant versus transporting the spent fuel to a centralized interim fuel storage facility and/or to a permanent repository at Yucca Mountain?

- What are the likely transportation means and corridors for spent fuel and high level radioactive wastes in California? Are California's regulations and programs adequate to address the shipment of such wastes through California? Are the current fees adequate to cover state costs for such activities as shipment inspections and escorts?

Long-Term Issues

The issues presented in the above section are of interest to state policymakers and other stakeholders and are associated with the currently operating nuclear power plants. Two other issues have policy implications for the longer term. The first issue is whether existing nuclear power plants should operate beyond their current licenses. The second issue is whether any new nuclear power plants should be constructed in the state.

Life Extension of Existing Plants

Plant upgrades and improved operating procedures may permit nuclear power plants to operate longer than initially envisioned. The NRC has granted operating license extensions to 19 nuclear power plants in other states and is reviewing applications for license extensions from another nine plants. (NRC 2005a) Normally, it takes about two years for NRC to reach a decision on such an application. If California decides to invest in maintaining the operating plants through their current operating licenses, then in another 5 to 10 years the utilities are likely to decide whether or not to apply for such license extensions. PG&E has indicated an interest in examining the feasibility of extending the license at Diablo Canyon and has proposed conducting a four year feasibility study beginning in 2007.(PG&E 2005d) The costs and benefits of such license extensions are substantially more uncertain than the steam generator replacement decisions facing the CPUC today.

Renewed Interest in Nuclear Power Plant Development

California law prohibits the construction of any new nuclear power plants in the state until the Energy Commission finds that the federal government has demonstrated, approved, and there exists a technology for the permanent disposal of spent fuel from these facilities. No reactors have been ordered in the U.S. since the early 1970s, however, there has been recent discussion at the national level of a renewed interest by some parties in pursuing limited development of new nuclear facilities in the U.S.

CHAPTER 3: COSTS AND BENEFITS OF CALIFORNIA'S COMMERCIAL NUCLEAR POWER REACTORS

This section identifies the benefits and costs of continuing to operate California's nuclear fleet and quantifies them where figures are available. It presents a "going-forward" cost analysis that estimates the incremental cost of continuing to operate these plants rather than shutting them down in 2005. This analysis does not include sunk costs, such as costs to construct the plants or contributions to the Nuclear Waste Fund, which is the fund designated to finance a federal nuclear waste repository.

Due to uncertainty over future gas prices, regulatory requirements, capital costs, and other costs, there are wide variations in the estimated levels of benefits and costs associated with the operation of nuclear power plants. Thus, for this assessment, we present bounding cases for the magnitude of these benefits and costs. Our assessment relies on publicly available information from multiple sources, including owners of California's nuclear facilities, regulatory agencies, and interveners in regulatory proceedings that examine the costs and benefits of the future operation of these plants.

This section is organized as follows. We first identify the benefits associated with the continued operation of the nuclear fleet and provide bounding case estimates, where available. Next we provide an overview of the historic costs to construct and operate these plants. We then identify major capital projects that will be required if these plants are to continue operating. We put these costs together with anticipated operating costs to calculate going-forward cost estimates for each plant. We then identify additional expenditures not included in the cost estimates, because they are difficult to quantify, uncertain, or sunk. Finally, we identify additional issues of concern to California's nuclear power industry.

Benefits of Nuclear Power

Nuclear plants offer specific benefits to California's electric ratepayers as well as to the citizens of California. This section identifies some of these benefits.

Energy Supply

California's existing nuclear fleet delivers baseload power supplies to central and southern California. Figure 3 and Figure 4 present the historic annual generation and capacity factors[7] from California's nuclear facilities since 1986 and from the Palo Verde plant since 1990.[8] As can be seen from Figure 3, there is significant year-to-year variation in the amount of power produced from these plants, with Diablo Canyon

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[7] A capacity factor represents the proportion of maximum plant output that is generated in a given period. It is calculated as (energy generated in period) /(plant capacity rating * hours in period).

[8] Palo Verde units came online between 1986 and 1988.

producing at steadier rates than SONGS or Palo Verde over the last decade.(NEI; PG&E 1985-2004; SCE 1985-2004)

Figure 3: Electricity Generation At California's Nuclear Plants

(millions of kWh (exclusive of plant use))

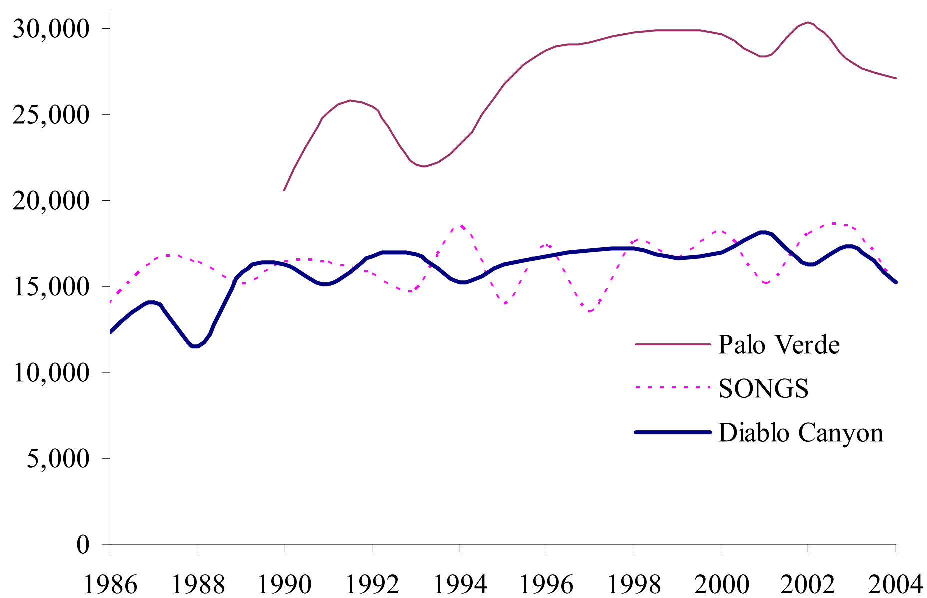
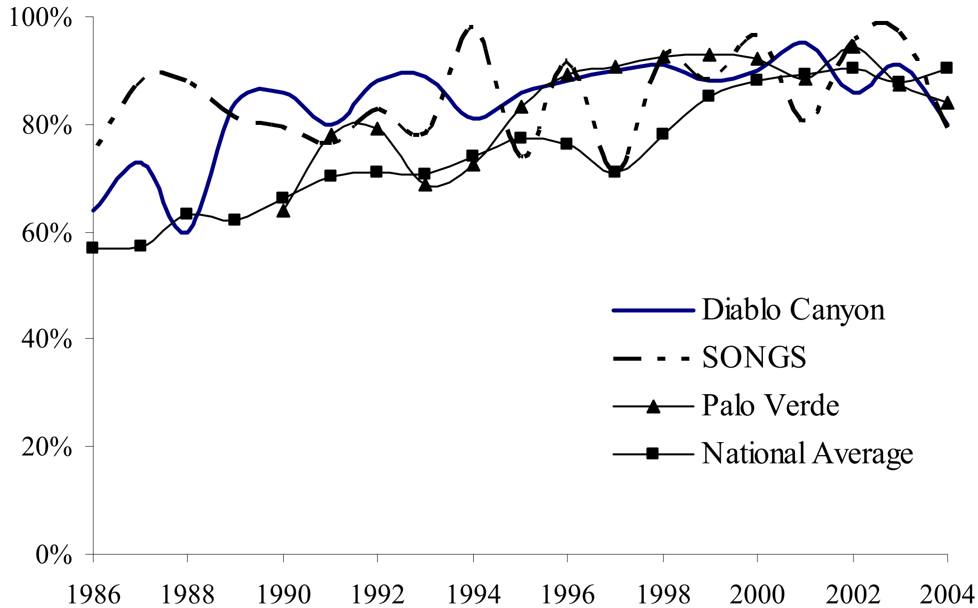


Figure 4 compares the capacity factors of California's plants with the average capacity factor for all U.S. nuclear power plants. Both California and average capacity factors have increased over time, with California's fleet generally exceeding the national average capacity figure. However, since 2000, the capacity factors of Diablo Canyon and SONGS have averaged slightly less than the national average, with their 2004 capacity factors approximately 12% below the national average.(NEI; PG&E 1985-2004; SCE 1985-2004)

Figure 4: Capacity Factors Of California's Nuclear Plants



One of the main determinants of a plant's capacity factor is the duration of its refueling outages. PG&E generally takes one of Diablo Canyon's units offline for refueling each year. Every three to five years, it takes both units offline. SCE takes from zero to two of SONGS' units offline each year.

Figure 5 shows the duration of refueling outages at Diablo Canyon in each year (averaged when more than one outage occurred in a year) superimposed by a linear trendline. The trendline highlights the overall reduction of time required to refuel Diablo Canyon, from an average of 105 days per outage in 1988 to 30 days per outage in 2002. The 2003 outage was unusually long at 51 days.

Figure 5: Duration of Refueling Outages at Diablo Canyon

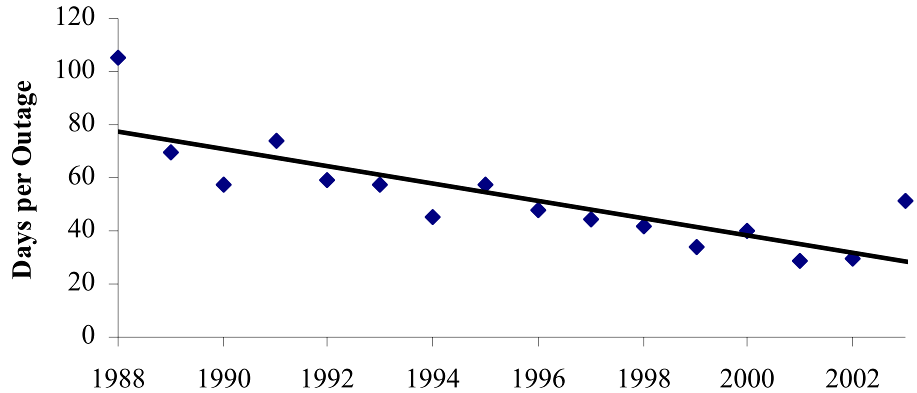
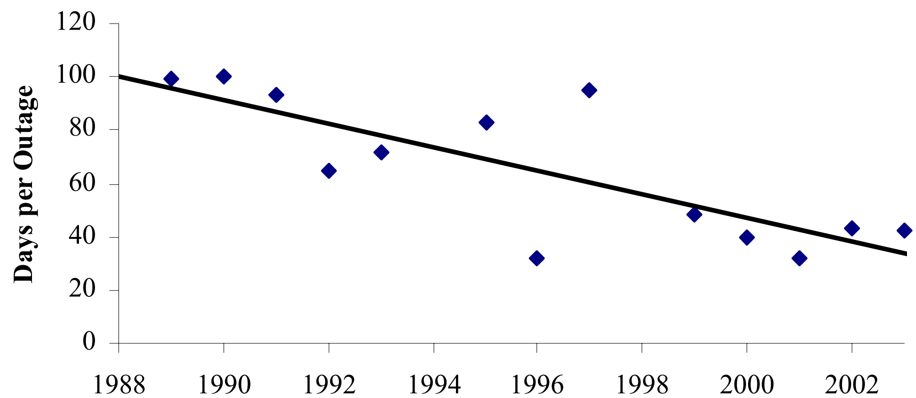


Figure 6 shows the duration of refueling outages at SONGS in each year. The duration of these outages has generally declined over the years, from an average of 86 days per outage from 1989 through 1993 to an average of 41 days per outage from 1999 to 2003. The 2004 outage at Unit 3 lasted an unusually long 92 days, due in part to the replacement of the unit's pressurized heater sleeve.

Figure 6: Duration of Refueling Outages at SONGS



Estimates of future generation from these plants vary. Table 2 presents a range of expected future capacity factors for the current fleet of California nuclear facilities along with their average historic capacity factors.[9] As is seen in this table, PG&E and SCE have both projected that their plants will perform better in the future than they have on average over the last ten years.

[9] These projections presume that the steam generators are replaced at all of the units and do not include capacity factors for the years in which the steam generators are replaced.

Table 2: Expected Future Capacity Factors of California's Nuclear Plants

	Average Historic Capacity Factors, 10-year average	Projected Future Capacity Factors	
Diablo Canyon	88.49%	PG&E	90.6%
		CPUC[10]	80%-90.6%
		TURN[11]	75%-90.6%
SONGS	85.65%	SCE	88%
		TURN	80%-88%

Value of Energy and Capacity

The energy and capacity supplied to California by nuclear power plants has value that is reflected in the cost that would have to be incurred to replace that energy and capacity in the event that the existing nuclear plants are shut down. Nuclear power plants represent a significant share of the existing power supply in California and the West. As such, the energy and capacity provided by these plants cannot simply be replaced using system power without causing considerable disruption to the power markets that determine the price for system power. Thus, the value of the existing resource is often estimated by calculating the cost of building replacement generation. This is the approach used by PG&E and other parties in the Diablo Canyon Steam Generator Replacement Project (SGRP) proceeding as well as by SCE and other parties in the SONGS SGRP proceeding.

Diablo Canyon Replacement Energy Costs

PG&E's application for the Diablo Canyon SGRP included testimony that estimated replacement energy costs under three scenarios.

1. The first scenario was based on the cost of purchasing replacement power at market prices assuming that replacement capacity in the form of natural gas combined cycle plants was placed in service at the time that the Diablo Canyon generators were retired. Without the SGRP, Diablo Canyon Units 1 & 2 are expected to shut down in 2014 and 2013, respectively.

2. The second scenario assumes that PG&E contracts with or builds 2200 MW of new combined cycle generation to be on-line by the date Units 1 & 2 are shut down.

3. The third scenario assumes that 10% of the replacement generation in Scenario 2 consists of new renewable generation.

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[10] (CPUC 2005a)

[11] The Utility Reform Network. Based on testimonies in the steam generator replacement proceedings, (CPUC 2004b) and (CPUC 2004d).

Each of these scenarios, to the extent that they rely upon gas-fired generation, depends on a forecast of natural gas prices. PG&E based its forecast of burner-tip natural gas prices on the September 5, 2003 closing price of forward contracts traded at the New York Mercantile Exchange (NYMEX) and broker quotes for the basis differential between the Henry Hub, LA trading point for NYMEX contracts and the delivery points on PG&E's natural gas system. Beyond 2008, PG&E extrapolated prices using a 1.1% escalation rate based on the observed average escalation in the price of forward contracts between 2006 and 2008. The high and low gas price scenarios are 40% above and below the base case forecast. PG&E's gas price forecasts are presented in Table 3.

Table 3: PG&E Forecast of Burner Tip Natural Gas Prices

($/MMBtu)

Year	Base	High	Low
2008	$5.22	$7.31	$3.13
2009	$5.28	$7.39	$3.17
2010	$5.34	$7.48	$3.21
2011	$5.41	$7.57	$3.25
2012	$5.47	$7.66	$3.28
2013	$5.54	$7.76	$3.32
2014	$5.61	$7.85	$3.36
2015	$5.67	$7.94	$3.40
2016	$5.74	$8.04	$3.45
2017	$5.81	$8.14	$3.49
2018	$5.88	$8.23	$3.53
2019	$5.95	$8.33	$3.57
2020	$6.02	$8.43	$3.61
2021	$6.10	$8.53	$3.66
2022	$6.17	$8.64	$3.70
2023	$6.24	$8.74	$3.75
2024	$6.32	$8.85	$3.79
2025	$6.39	$8.95	$3.84

Source: (PG&E 2004c, p.6-6)

PG&E's estimated average costs of replacement power are presented in Table 4.

Table 4: PG&E Forecast of Replacement Power Costs

($/MWh)

Year	Scenario 1	Scenario 2	Scenario 3
2008	42.7	NA	NA
2009	45.6	NA	NA
2010	49.2	NA	NA
2011	51.9	NA	NA
2012	53.6	NA	NA
2013	55.4	57.3	57.1
2014	56.6	57.9	57.8
2015	57.7	58.4	58.3
2016	58.8	59.1	58.8
2017	59.8	59.8	59.5
2018	60.6	60.6	60.3
2019	61.3	61.3	61.1
2020	62.1	61.9	61.7
2021	62.9	62.2	61.9
2022	63.7	62.9	62.4
2023	64.5	63.7	63.2
2024	65.3	64.4	63.9
2025	66.0	59.3	57.6

Source: (PG&E 2004c, p. 6-7)

Based on these replacement power costs and forecasted future generation at Diablo Canyon, PG&E estimated the following total alternative resource costs, expressed as the 2003 present value of replacement power.

Table 5: PG&E Forecast of Replacement Power Costs

($ million)

Year	Scenario 1	Scenario 2	Scenario 3
2003 PV	$3,148	$3,149	$3,135

Source: (PG&E 2004c, p. 6-2)

The Utility Reform Network (TURN), a ratepayer advocacy group, also submitted testimony in the Diablo Canyon SGRP proceeding. The TURN testimony took issue with PG&E's replacement power cost estimates, noting that in calculating the cost of a combined cycle PG&E assumed a facility life of 20 years. TURN advocated for the use of 30 years, pointing out that both SCE and SDG&E had used a 30 year life in other applications. TURN also pointed out that September 2003 natural gas prices were out of date and that PG&E had subsequently used April 19, 2004, prices in its long-term resource plan filings, which were lower than the September 2003 prices. The CPUC in D.05-02-052 concurred with both of these arguments and ordered that the cost-effectiveness analysis consider both the September 2003 and April 2004 gas prices and that the combined cycle costs be calculated using a 30-year life, which have the effect of lowering replacement power costs.

SONGS Replacement Energy Costs

SCE has also prepared testimony on the cost effectiveness of replacing the steam generators at SONGS Units 2 & 3. As in the case of Diablo Canyon, the cost of replacement power is central to this determination. SCE based its estimate of replacement power costs on the assumption that 2150 MW of combined cycle power plants would be built in California and Arizona. SCE conservatively estimated the construction cost of a new combined cycle plant at $625 per kW in 2004 dollars. For its gas price forecast, SCE relied on a forecast developed by Global Insight.

Table 6 presents the SCE forecast of prices at Henry Hub in constant 2004 dollars, as presented in SCE's application, and in nominal dollars calculated using an escalation rate of 2.5% per year.

Table 6: SCE Forecast of Henry Hub Natural Gas Prices

($/MMBtu)

Year	$2004	$Nominal
2007	3.43	3.69
2008	3.46	3.82
2009	3.46	3.91
2010	3.56	4.13
2011	3.76	4.47
2012	3.83	4.67
2013	3.89	4.86
2014	3.92	5.02
2015	4.00	5.25
2016	4.05	5.45
2017	4.07	5.61
2018	4.10	5.79
2019	4.13	5.98
2020	4.15	6.16
2021	4.17	6.35
2022	4.20	6.55

SCE used a revenue requirements model to determine the cost of replacement power based on the installed cost of replacement generation and the cost of baseload energy from these combined cycle plants. SCE estimates the cost of replacement generation assuming SONGS is shut down in 2009 to equal $1.7 billion on a present value basis ($2004). The additional electricity production costs are estimated to have a 2004 present value of $3.5 billion.

In its rebuttal testimony, TURN presented a summary of SCE's base case scenario that included the forecast of replacement power costs expressed in dollars per MWh shown in Table 7.

Table 7: Forecast of SCE Replacement Power Costs

Year	Replacement Power Cost ($/MWh)
2009	46.39
2010	48.36
2011	51.23
2012	53.11
2013	54.96
2014	56.61
2015	58.76
2016	60.70
2017	62.41
2018	64.26
2019	66.17
2020	68.04
2021	69.95
2022	72.03

Market Price Referent

The CPUC recently adopted a market price referent in its renewable portfolio standard proceeding that is useful for gauging the cost of replacement power. (CPUC 2005b) In this proceeding, the market price referent is intended to represent the price that utilities would pay for new power supplies from conventional (i.e., non-renewable) resources with contracts of 10, 15 or 20 years. In 2004, the CPUC conducted workshops and hearings to determine the most appropriate method for determining the market price referent. For baseload power it was determined that the combined cycle gas turbine fueled with natural gas would be the referent technology. Natural gas prices were based in the near term on forward contract prices traded over a 20 day period in August 2004 and in the long term on the escalation rate implicit in a selected long term price forecast. The adopted referent prices for the 2004 RPS contracts are $57.8 per MWh for 10-year contracts, $58.8 per MWh for 15-year contracts, and $59.9 per MWh for 20-year contracts. At these prices, the nuclear energy supplied to California in 2004 (about 35.5 million MWh) would be valued at roughly $2 billion, although given volatility in gas prices the range of replacement costs is more likely between $1.5 billion and $2.5 billion per year.

Grid Reliability

The locations of Diablo Canyon and SONGS provide substantial grid reliability benefits for California. This section summarizes studies that have attempted to quantify these benefits.

ISO Studies

The CAISO staff has studied the impact of a SONGS or Diablo Canyon shutdown on the CAISO-controlled grid.(CAISO 1999; CAISO 2000) Each study is discussed below.

In its study of SONGS, the CAISO staff found that a significant number of mitigation measures would be required were SONGS to permanently shut down. Mitigations would include construction of a 500 kV line, reconductoring existing 230 kV lines, installing shunt capacitors and static VAR devices, reducing area import capabilities, or dropping load. The CAISO report noted that installation of new generation reduces the need for some of these transmission upgrades but does not eliminate them.

The CAISO staff identified two transmission-only mitigation scenarios and two mitigation scenarios involving both new generation and transmission resources. In addition to specific transmission or generation resources, each scenario assumed a common set of transmission upgrades:

- Upgrade the conductors on SCE's Del Amo - Ellis and Barre – Ellis 230 kV lines, and form a second Barre-Ellis 230 kV line
- Install 750 MVAR of shunt capacitors on the SCE system
- Bypass the SWPL series compensation
- Install series compensation (75 percent) on the four 230 kV lines north of SONGS or construct a new 15 mile Ellis-Santiago 230 kV line

The first transmission-only mitigation scenario, which focused primarily on 230 kV system upgrades, assumed the installation of 4,460 million volts-ampere-reactive (MVAR) support, mostly dynamic, in both SCE and SDG&E systems. The amount consisted of 750 MVAR of switched shunt capacitors and 3,600 MVAR of dynamic VAR sources for the SCE system and 82.5 MVAR of switched shunt capacitors and 27.5 MVAR of dynamic VAR sources for the SDG&E system.

The second transmission-only mitigation scenario, which focused primarily on 500 kV transmission system facilities, assumed the installation of the Valley-Rainbow 500 kV line including a 230 kV connection to SDG&E’s system and installation of 3,300 MVAR reactive power support in both SCE and SDG&E systems. The reactive power support consisted of 750 MVAR of switched shunt capacitors and 2,400 MVAR of dynamic VAR sources for SCE, and 120 MVAR of switched shunt capacitors and 30 MVAR of dynamic VAR sources for SDG&E.

The first generation/transmission mitigation scenario assumed construction of up to 3,000 MW of new generation in the Orange County area. It was assumed that this generation consisted of repowering existing power plants at Alamitos, Huntington Beach, and San Bernardino. In addition, this scenario assumed installation of 2,100 MVAR reactive power support in both SCE and SDG&E systems. The amount consisted of 750 MVAR of switched shunt capacitors and 1,200 MVAR of dynamic VAR sources in SCE's area, and 120 MVAR switched shunt capacitors and 30 MVARs of dynamic VAR sources in SDG&E's area.

The second generation/transmission mitigation scenario assumed construction of the proposed Otay Mesa Power Plant near Miguel Substation and installation of shunt capacitors (25-75 MVAR for SDG&E and 100 MVAR for SCE). It should be noted that this scenario assumes a significant reduction in import capability by SDG&E.[12] The CAISO staff did not provide estimated costs for these mitigation packages.

The CAISO staff's assessment of a permanent shutdown of Diablo Canyon found that no transmission-related mitigation would be required to maintain transmission system reliability and to allow the CAISO to operate the transmission system reliably. The study did find that the shutdown of Diablo Canyon would reduce south to north transfer capability on Path 15 and north to south transfer capability on Path 26. (CAISO 2000)

SCE Study

As shown in Figure 7, SONGS is located between the SCE and SDG&E service territories, a key location in the California transmission grid. In A.04-02-026, SCE explained that if SONGS were to shut down, significant transmission mitigation would likely be required in addition to the development of new generation resources. SCE proposed three different transmission mitigation scenarios.(SCE 2004, p.4) One of these scenarios involved upgrades to the 230 kV system; the other two scenarios involved development of alternative 500 kV transmission lines. The upgrades to the 230 kV system would involve upgrading the Barre-Ellis line and adding 2,520 MVAR of series SVC dynamic reactive devices. It is estimated that this upgrade would cost $287 million (2004$) and be completed by 2009. One of the 500 kV scenarios involved construction of a transmission line from the Imperial Valley substation in SDG&E's service territory to the Ramona substation. This scenario would also involve upgrades to Path 49 and the addition of 1,374 MVAR of series static var compensator[13] (SVC) dynamic reactive devices. It is estimated that this upgrade would cost $673 million (2004$) and be completed by 2009. The second 500 kV scenario involves construction of the Valley-Rainbow line (with a small addition to the proposed scope of this project) and 924 MVAR of series SVC dynamic reactive devices. It is estimated that this upgrade would cost $491 million (2004$) and be completed by 2009.[14] For each of these scenarios, it was

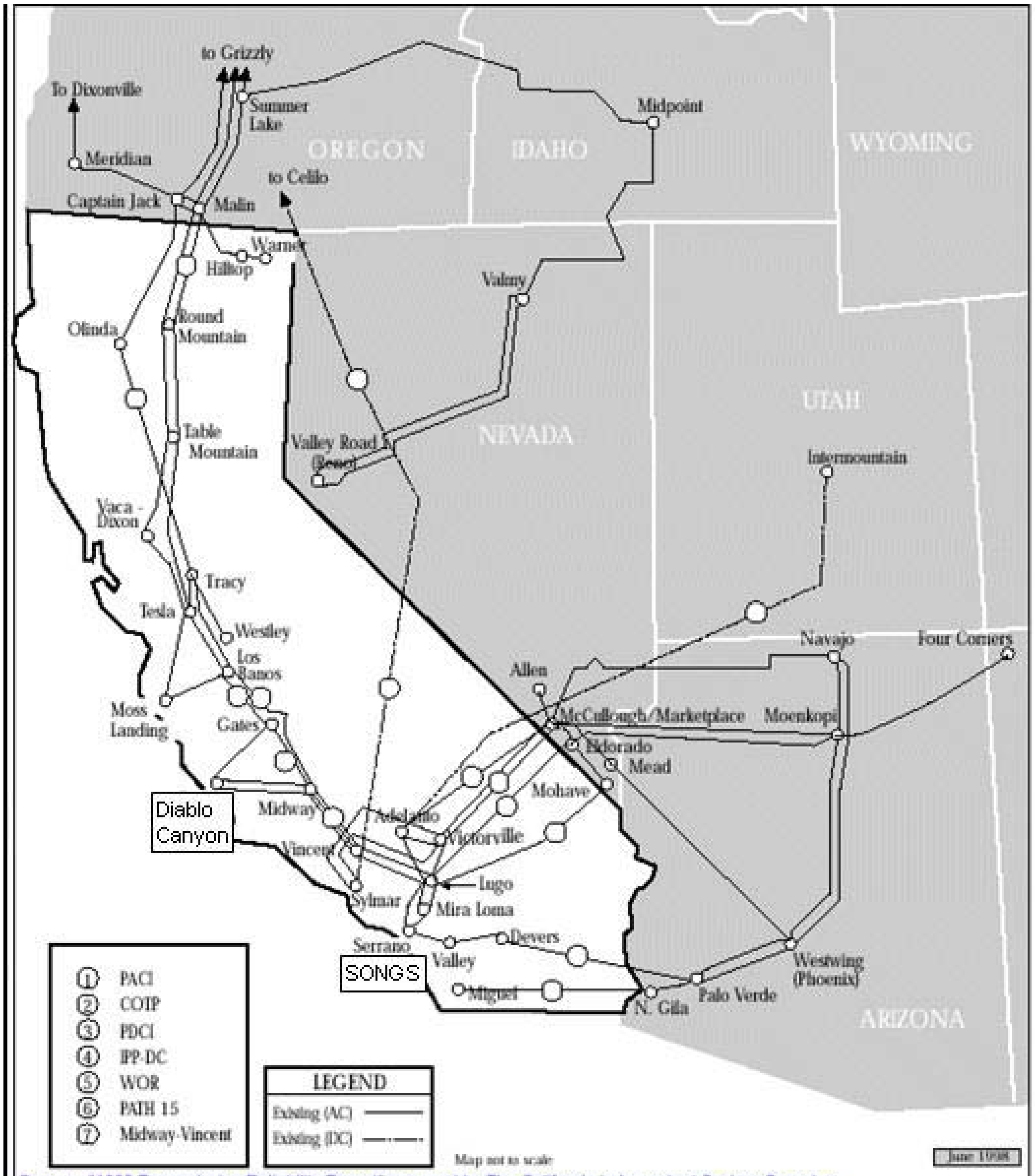
[12] Unlike the other scenarios, this mitigation option does not require the bypassing of the Southwest Powerlink series capacitors.

[13] A static VAR compensator regulates voltage by generating or absorbing reactive power.

[14] Note that SCE assumes that the Valley-Rainbow transmission line is unlikely to be built since this project has been rejected twice by the CPUC.

assumed that the Devers-Palo Verde No. 2 line and upgrades to the Southwest Powerlink are implemented (with a cost of approximately $700 million). (SCE 2004, p.5)

Figure 7: Major Transmission Lines in California



Source: "1998 Transmission Reliability Report" prepared by The California Independent System Operator.

Many of the intervenors in this proceeding disputed the assumptions that SCE used in its transmission study analysis. Aglet and SDG&E pointed out that some of these transmission upgrades are likely unavoidable, even if the steam generators are replaced. (SDG&E 2004, RS-1; Aglet 2004, p.6) ORA noted a number of perceived flaws in SCE's analysis, including double-counting of a substation in the Valley-Rainbow case and using estimates for MVAR dynamic reactive support devices that are twice as high as necessary, based on post-transient load flow analysis and comparison with PG&E's

actual installation costs. (ORA 2004, p.8) SDG&E concluded that “the results from this study, based on inaccurate system modeling and invalid input assumptions, are not credible.” (SDG&E 2004, RS-2)

Summary Of Potential Grid Reliability Benefits

In summary, SONGS appears to provide significant grid reliability benefits as a result of its site between the SCE and SDG&E service territories. According to the CAISO, Diablo Canyon, on the other hand, does not provide much in the way of grid reliability benefits. SCE estimates the costs of transmission mitigation resulting from a shutdown of SONGS to be between $287 million and $673 million (2004$).

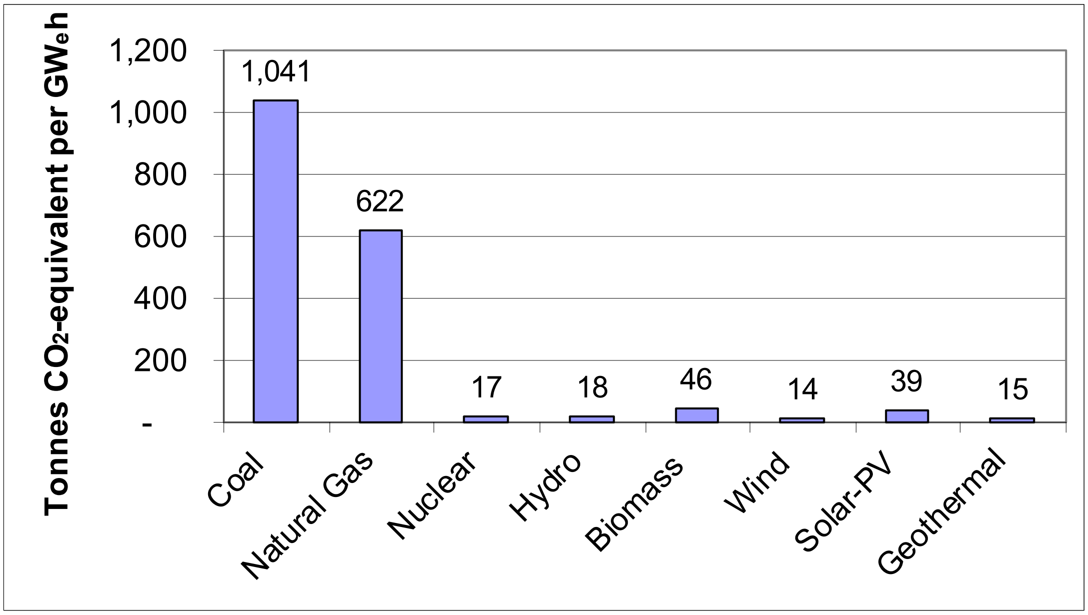
Avoided Atmospheric Emissions

Leading scientists across the country recognize the “greenhouse effect” – the existence of a heat-trapping layer of gases surrounding the earth. The overall warming that occurs when concentrations of GHG increase in the atmosphere is referred to as “climate change.” While consensus has yet to be reached on the timing and magnitude, most scientists now agree that climate change is occurring, is caused by human activities, and could severely affect natural ecosystems and the world’s economy.(Energy Commission 2005d) The National Academy of Sciences has reported that “abrupt climate changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies.” They have predicted that most of the climate changes over the next century will be in response to human activities, such as the production of greenhouse gases and aerosols, and that these human activities may also increase the possibility of “large, abrupt, and unwelcome regional or global climatic events.” (NAS 2002; NAS 2003)

Fossil-fueled power plants emit carbon dioxide and other pollutants as a byproduct of combustion. Other emissions from fossil fuel combustion, such as nitrogen oxides and particulates, result in environmental degradation, health problems, and other damage to society. As shown in Figure 8, nuclear power plants emit very few greenhouse gases. They also emit very few other pollutants. Thus, nuclear generation results in a net reduction of emissions compared to a scenario in which existing nuclear generation was replaced by either existing generation or new fossil-fired generation.

There are two steps to estimating the avoided emissions benefits of nuclear power. First, it is necessary to estimate the amount of emissions that are avoided by nuclear power. One approach is to simply rely on the system-average emissions rates for the current system and to assume that these emissions would have occurred in the absence of California’s nuclear power plants. Another approach is to assume, on a going forward basis, that nuclear power avoids emissions from new generating facilities (assumed to be gas-fired combined cycles).

Figure 8: Comparison of Life-Cycle CO_2 Emissions



Source: (NEI 2005c)

Table 8 presents the estimated level of emissions associated with power production in the western U.S. and in California, along with estimated levels of emissions from a new natural–gas fired combined cycle plant.

Table 8: Power Plant Emissions

	CO2, lb/MWh	NOx, lb/MWh	PM10, lb/MWh
WECC 2000 emissions, U.S. only	1,045	1.84	N/A
California statewide emissions, 2000	633	0.56	0.06 (2003)
Combined Cycle	230	0.35	0.01

Sources: (Energy Commission 2005b, p.58; LBNL 2002; NEI 2005c; EPA 2000)

Second, in order to estimate the avoided emissions benefits of nuclear power, it is necessary to place a value on avoided emissions. These estimates can be highly controversial, with wide ranges of values having been assigned to each pollutant. The CPUC considered the value of avoided greenhouse gas emissions in D.04-12-048 and found estimates ranging from approximately $8 to $25 per ton. It ruled in that decision that utilities should choose a value in this range and justify their choice for use in evaluating bids in the utilities' long-term resource solicitations. Values for other avoided emissions have been estimated in conjunction with the CPUC's ongoing Rulemaking related to avoided costs, R.04-04-025. (CPUC 2004c)

For this assessment, we assume that the base case value for greenhouse gas emissions is $8 per ton, with an upper bound of $25 per ton, consistent with the CPUC's decision in 2004. We also use the values of $4.629/lb for NOx and $6.475/lb for PM10, as adopted by the CPUC in R.04-04-025 for other pollutants.

While there are no greenhouse gas emissions from nuclear powered electricity generation, there are some emissions from nuclear plant construction, uranium mining and enrichment, and other routine plant operations. The emissions avoided through the use of nuclear generation are determined by subtracting the emission associated with nuclear generation from the average emission levels shown in Table 8.[15] (NEI 2005c) Table 9 shows the value of the emissions saved by using California's nuclear fleet in place of plants that emit at the average rate for the WECC region or California or in place of a gas-fired combined cycle plant.

Table 9: Annual Emissions Savings From California's Nuclear Fleet

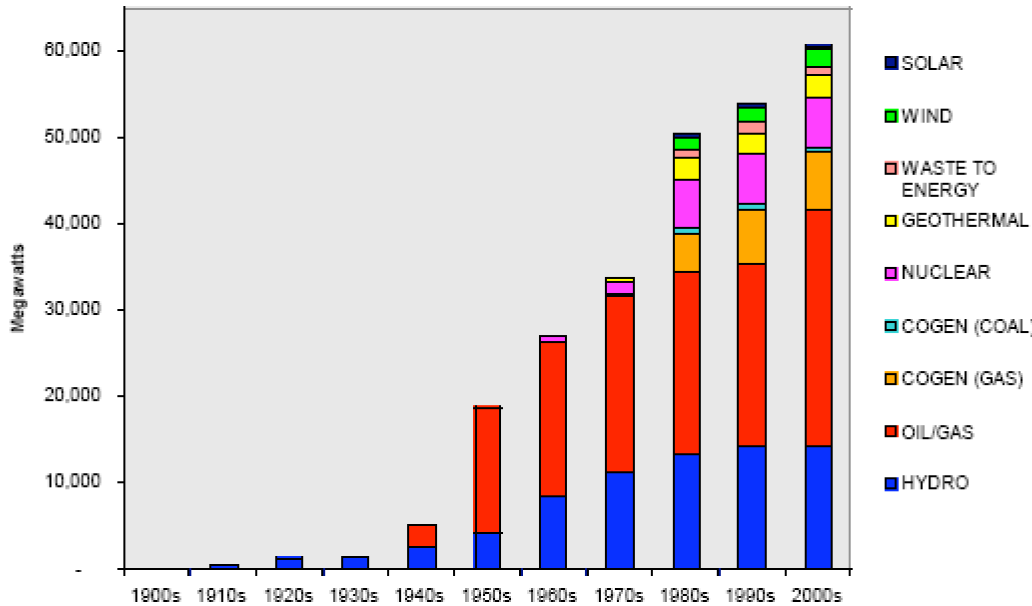
	Emissions Avoided through Nuclear Generation, lb/MWh			Value of Incremental Emissions $/MWh	Annual Emissions Savings from Nuclear Plants, millions of dollars			
					Base Case		High Case	
	CO_2	NOx	PM10	Total	Diablo Canyon	SONGS	Diablo Canyon	SONGS
WECC average	978	1.78	N/A	$12.15	$204	$199	$343	$335
California average	566	0.51	0.06	$4.96	$83	$81	$164	$160
Combined Cycle	163	0.29	0.01	$2.04	$34	$33	$57	$56

Fuel Diversity

California's resource mix consists of a wide range of power sources that rely on a range of fuels. Figure 9 presents California's fuel mix over the last century. As can be seen from this figure, the state has a relatively diverse fuel mix. This diversity provides California with a partial hedge against dramatic price increases in any particular fuel source. However, it can also be seen from this figure that recent generation additions have been dominated by gas-fired generators. As new gas-fired generation comes online, it is expected that natural gas usage in the state will increase relative to other fuel sources. Should this trend continue, California's fuel mix will become less diverse in the future.

[15] The NEI estimates lifecycle greenhouse gas emission from nuclear plants: 67 lbs CO_2/MWh; 0.06 lbs NO_x/MWh; 0.004 lbs PM_{10}/MWh.

Figure 9: Cumulative Generating Capacity In California By Fuel Type



Source: (Energy Commission 2005b)

Nuclear power provides a significant hedge against increases in fossil fuel prices. Should California's nuclear fleet cease operations, much of the new generation sources that would replace the nuclear plants could be expected to use natural gas. Thus, nuclear power provides a significant fuel diversity benefit to customers.

Reduction in Natural Gas Prices

Because nuclear power plants do not burn natural gas, the shutdown of California's nuclear fleet could result in a significant increase in natural gas usage in California. Global Insight (consultants for SCE) estimated that the shutdown of SONGS and Diablo Canyon would increase statewide gas demand by about 0.7 Bcfd, or about 10% of California's total gas demand, assuming that the generating capacity for SONGS and Diablo Canyon is replaced by new or existing gas-fired combined cycle plants. (SCE 2004, chapter V workpapers p.621) Because California's supply curve for natural gas is upward sloping, an increase in demand would result in an increase in natural gas prices. SCE's consultant estimated that the shutdown of SONGS alone would increase natural gas prices at Topock by about $0.11 per MMBtu under their base case assumptions, while a shutdown of both SONGS and Diablo Canyon would increase gas prices at Topock by $0.17 per MMBtu under base case assumptions. (SCE 2004, chapter V workpapers p.623) Should no LNG be developed on the west coast, the shutdown of SONGS would result in an increase in Topock gas prices of $0.06 per MMBtu, while a complete shutdown of nuclear facilities in California would increase natural gas prices at Topock by $0.08 per MMBtu. (SCE 2004, chapter V workpapers p.624)

Intervenors in the case objected to the magnitude of benefits that SCE purported arise from SONGS' effect on reducing natural gas prices. TURN noted that "replacement of a significant portion of SONGS by a mix of renewables and efficiencies (or even modern coal-fired generation) at a similar cost to gas would reduce or eliminate any potential gas price increase." (TURN 2004a, p.6)

It is important to note that the shutdown of SONGS and Diablo Canyon would increase natural gas prices not only for electric generators but for all natural gas consumers in California. In other words, using SCE's assumed natural gas demands from Global Insight, the shutdown of SONGS and Diablo Canyon would result in an increase in statewide natural gas costs of approximately $481 million per year in SCE's basecase and by $226 million per year in the scenario where no LNG is constructed in California. (Energy Commission 2005c)

The expected increase in gas prices due to the reduction in nuclear generation has also been studied indirectly by Lawrence Berkeley National Laboratory (LBNL). (LBNL 2005) The LBNL effort focused on the reduction in natural gas prices as a result of renewable resources and energy efficiency. The LBNL study reports that renewable programs and energy efficiency put downward pressure on natural gas prices. As electricity previously provided by gas-fired electricity generators is provided by renewable energy sources or is conserved through energy efficiency, the demand for natural gas is reduced and the demand curve shifts inward resulting in a lower overall price for natural gas. This effect is increasingly cited as justification for policies promoting renewable energy and energy efficiency.

According to the LBNL study, every 1% reduction in nationwide gas demand produces a reduction in wellhead gas prices of between .8% and 2%. (LBNL 2005, p.18) This translates into gas bill savings of $7.50-$20 for each MWh of incremental renewable energy. (LBNL 2005, p.15) Using the LBNL model, it is possible to estimate the reduction in current natural gas prices that will result in the future due to the continued operation of SONGS and Diablo Canyon. Table 10 presents these results.

Table 10: Reduction Of Natural Gas Prices Due To California's Nuclear Fleet

	Ten-Year Average Annual Generation, MWh	Annual Natural Gas Price Reduction, millions of dollars
Diablo Canyon	16,778,816	$126-$336
SONGS	12,275,816	$92-$246
Total	29,054,631	$218-$581

The SCE and LBNL studies used two different approaches to estimate the gas price reductions that result from the operations of SONGS and Diablo Canyon. The SCE study found these savings to be between $226 and $481 million per year for Californians alone. The LBNL study found these savings to be between $218 and $581 million nationwide.

Historic Trends In Long-Term Costs

The prior section discussed the benefits of nuclear power, including its impacts on the transmission grid, natural gas prices, and the environment. Much of the remainder of this chapter considers the going-forward costs of these plants. For historical context, we also present an overview of the historic costs associated with constructing, operating, and maintaining California's nuclear plants.[16]

Capital Costs

Diablo Canyon Capital Costs

Construction costs at Diablo Canyon exceeded the initial $320 million estimate (1968 dollars) by over five billion dollars. PG&E requested in A.84-06-014 to recover $5.5 billion of these costs in its rate base. Ratepayer advocates and the California Attorney General requested that only $1.1 billion be recoverable.(CPUC 1988) The dispute was settled in 1988 by shifting the risks of full recovery of sunk capital costs and future capital expenditures from ratepayers to shareholders using performance-based pricing, in which PG&E was paid a fixed rate per energy generated regardless of production costs. The rate was constructed so as to disallow $2 billion of PG&E's costs over the plant's lifetime if the plant operated at a 58% capacity factor, which was the average capacity factor for a nuclear power plant at that time. (CPUC 1988)

Under this regulatory structure, annual capital expenditures at Diablo Canyon fell from $168/kW[17] in 1987 to $54/kW in 1988 and an average of $48/kW-yr through 1995. During this same period, the plant operated at 82% capacity factor, providing PG&E with much higher revenues than DRA had anticipated. DRA accused PG&E of overcollecting on Diablo Canyon. The parties settled on an agreement that maintained the same ratemaking structure with reduced per-kWh payments. (CPUC 1995a) In 1997, in preparation for industry restructuring, Diablo Canyon's cost recovery was converted to an Incremental Cost Incentive Price (ICIP) mechanism, wherein PG&E was rewarded for keeping costs down and penalized for letting them rise too high.(CPUC 1997) PG&E's recovery rate dropped from 11.9¢/kWh in 1994 under the settlement agreement (CPUC 1988) to 3.26¢/kWh in 1997 under ICIP. (CPUC 1997) Capital expenditures dropped accordingly, averaging $4/kW-yr from 1998 through 2001.[18] Expenditures rose once again in 2002, when cost recovery ratemaking replaced ICIP (CPUC 2002) and security costs increased in the wake of the September 11, 2001 terrorist attacks. In part due to security cost increases, capital expenditures rose 473% in 2004 from $7/kW to $40/kW or $94 million.

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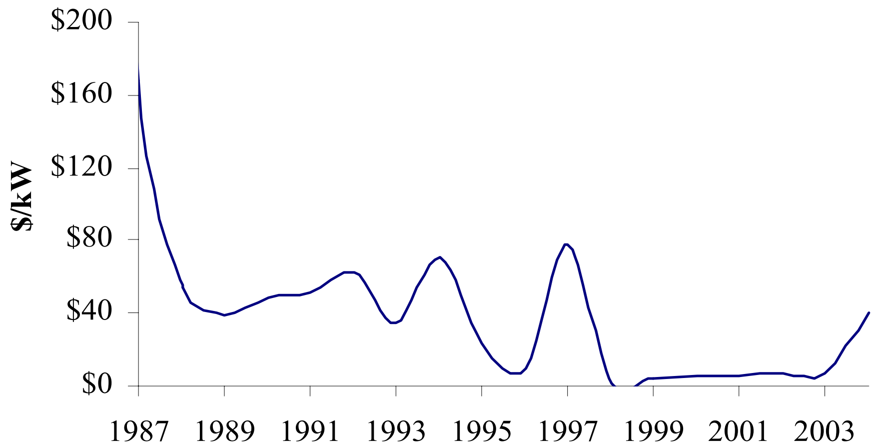
[16] This section on historic costs is provided only as background information for the going-forward cost analysis presented below. The costs mentioned here are not included in the going-forward cost analysis.

[17] All data have been converted to 2004 dollars using the Gross Domestic Product chain-type price index unless otherwise indicated.

[18] Diablo Canyon's Incremental Cost Incentive Price mechanism was approved on May 21, 1997 with D.97-05-088 and remained in effect through 2001. (CPUC 1997)

Figure 10: Historic Per-kW Capital Expenditures At Diablo Canyon



SONGS Capital Costs

Construction costs at SONGS likewise far exceeded initial estimates. Units 2 and 3, which were estimated to cost $436 million (1971 dollars), ultimately cost more than $4.5 billion. Capital additions at the three SONGS units were also high in the early years, exceeding $700/kW in 1986. Costs fluctuated wildly over the next couple of years, dropping to $124/kW in 1987 and up to $430/kW in 1988.[19] (SCE 1985-2004) In 1992, SONGS Unit 1 was retired in response to continued operational difficulties and to the costly upgrades reflected in some of these expenditure spikes. (CPUC 1992) From 1989 through 1995, capital expenditures remained fairly steady, ranging from $75/kW-yr to $114/kW-yr. Expenditures dropped to $42/kW in 1996, when an ICIP program was implemented at SONGS, and stayed low through 2001, averaging $40/kW-yr during this period. Costs rose in 2002 due to the increased security requirements and fell back down to $49/kW in 2003. Capital costs rose again in 2004 to $95/kW as ICIP ended and security costs increased.[20] Overall, capital costs at SONGS have averaged $63/kW-yr over the last ten years.

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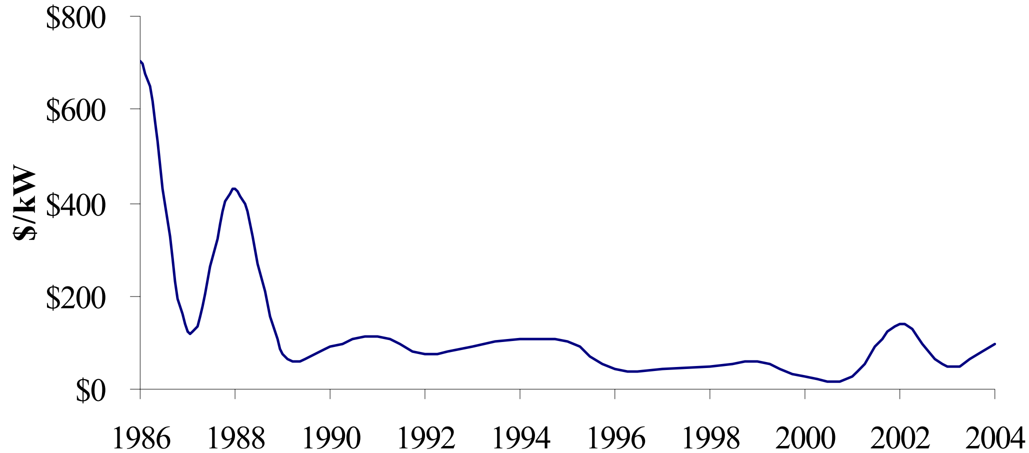
[19] Costs of SONGS 1 are included through 1991. Post-1991 decommissioning costs are excluded, to the extent that they are identified as such in the FERC Form 1 data.

[20] Of the $143 million in 2004 capital expenditures, $67 million were attributed special security projects. (SCE 2005a)

Figure 11: Per-kW Capital Expenditures at SONGS

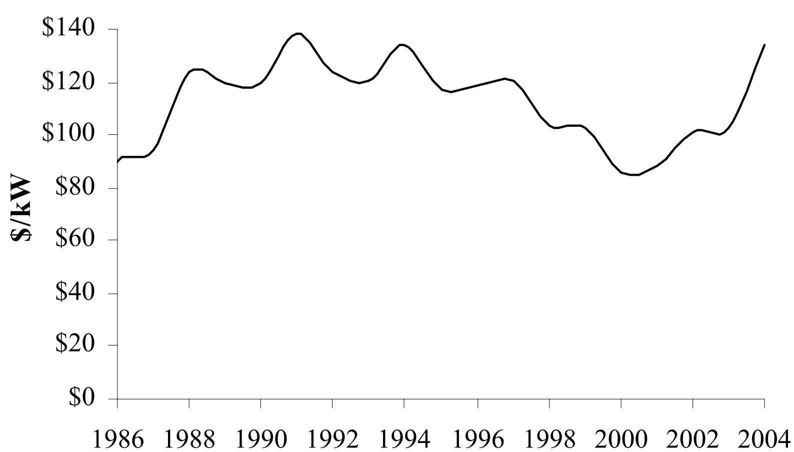


O&M Costs

Diablo Canyon O&M Costs

O&M expenses at Diablo Canyon fluctuate regularly according to the schedule of refueling outages and in response to regulatory pricing changes and security concerns. Expenses were relatively low under ICIP and began rising substantially in 2002, when ICIP had expired and security requirements had increased.

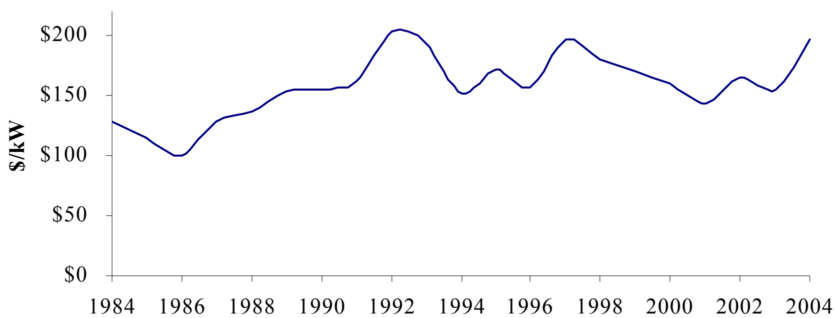
Figure 12: Per-kW Non-Fuel O&M Expenses at Diablo Canyon



SONGS O&M Costs

O&M expenditures at SONGS fluctuate in part based on the number (from zero to two) and duration of refueling outages occurring in each year, each of which now costs on the order of $60 million. (SCE 2004) These costs have been consistently higher at SONGS than at Diablo Canyon. Between 1995 and 2004, non-fuel O&M expenditures have averaged $170/kW-yr at SONGS and $107/kW-yr at Diablo Canyon.

Figure 13: Per-kW Non-Fuel O&M Expenses at SONGS



Anticipated Major Capital Projects

This section describes anticipated major capital projects that will drive the going-forward costs of California's nuclear fleet. The largest project is the steam generator replacement project, discussed first. Costs of these projects are included in the going-forward cost assessment.

Steam Generator Replacement Project (SGRP)

The projected costs to operate and maintain California's nuclear power plants depends in large part on whether or not their proposed steam generator replacement projects are approved. The steam generators use heat from water circulated through the reactor to evaporate another stream of water into steam that runs the turbines. (CPUC 2005a, p.4) They were initially intended to last the lifetime of the plants, but they have degraded and need to be replaced. The replacement projects, which would cost on the order of $750 million per plant, likely need to be completed if the plants are to continue operating through the remainder of their operating licenses.

Similar degradation has been observed at all other U.S. pressurized water reactors, (PG&E 2004c, p.1-1) including Palo Verde. Palo Verde Unit 2's steam generators were replaced in 2003 at a total cost of about $412 million. (PWCC 2005) Steam generators for Palo Verde's two other units are expected to be replaced in 2005 and 2007-2008, respectively. SCE's share of these costs is estimated to be about $115 million. (SCE 2005b, p.19)

PG&E and SCE have applied to the CPUC for permission to recover costs associated with the steam generator replacements at Diablo Canyon and SONGS. (CPUC 2004b; CPUC 2004d)

Diablo Canyon SGRP

PG&E's application to replace Diablo Canyon's four steam generators has been approved by the CPUC on an interim basis pending the approval of the project's environmental impact report, which will be decided in September 2005. The CPUC has authorized $706 -$815 million to replace Diablo Canyon's steam generators, with no after-the-fact reasonableness review if the project is completed for less than $706 million (unless the CPUC has reason to believe the costs to be unreasonable). (CPUC 2005a) PG&E's original cost estimate had projected that the steam generators would be procured for $182 million, but they have in fact been procured for $209.3 million, 15% higher than expected. The $815 million cap was set 15% higher than the projected cost of $706 million to account for such cost overruns. (CPUC 2005a, p.11)

PG&E has already contracted with Westinghouse to fabricate the eight steam generators and will be obligated for about $70 million of work that will be completed by September 2005, regardless of whether the project obtains final approval. (PG&E 2005b, pp. 62-63)

If final approval is granted, PG&E plans to replace Diablo Canyon's turbines and steam generators in 2008 (Unit 2) and 2009 (Unit 1) and continue to operate the plants through the end of their licenses in 2024 (Unit 1) and 2025 (Unit 2). If permission is not granted, the plants will likely be required to shut down in 2013 (Unit 2) and 2014 (Unit 1). (CPUC 2005e)

Many of the intervenors in the Diablo Canyon SGRP proceeding expressed concerns that the project and future operations of the facility would be more expensive than predicted and would yield fewer benefits.

- Aglet proposed that ratepayers be guaranteed $600 million in savings, half of the savings that PG&E forecast. The CPUC rejected this idea but limited ratepayers' risk by imposing the $815 million cap on recoverable funds. (CPUC 2005a, pp. 3, 44-47)

- TURN raised the concern that PG&E had modeled only a narrow range of circumstances in its cost-benefits analysis. TURN witness Bill Marcus modeled additional scenarios with a range of capacity factors and O&M and capital expenses, and with the possibility of an unanticipated year-long outage or early plant closure. (TURN 2004c) These scenarios had benefits ranging from negative $1.2 billion to $1.3 billion. (TURN 2004a, Table 1) The CPUC asked PG&E to run additional models that incorporated some of these concerns. It found that most cases, including its most likely case, yielded positive benefits, with benefits ranging from negative $152 million to $804 million. (CPUC 2005a, p.41)

- TURN also noted a number of assumptions embedded in PG&E's model that underestimate true costs, such as zero incremental decommissioning costs for Diablo Canyon for ten years, zero risk of a major accident, the NRC's extending the operational date of Unit 1 through 2024,[21] and the NRC's not imposing additional security requirements that will require incremental security funds. (TURN 2004b, p.24) The CPUC rejected most of these concerns as not sufficiently quantifiable. The cost analysis below takes some of them into account.

SONGS SGRP

SCE has requested cost recovery for its share of the $680 - $813 million that it anticipates will be the cost of replacing the steam generators at its SONGS 2 and SONGS 3 units. The CPUC is currently considering this request. It is expected to make its final decision in September 2005. (SCE 2005b, p.19)

If final approval is granted, SCE plans to replace SONGS' steam generators in 2009 (Unit 2) and 2010 (Unit 3) and continue to operate the plants through the end of their licenses in 2022. SCE projects that if permission is not granted, the plants will be required to shut down in 2009 (Unit 2) and 2010 (Unit 3). (SCE 2005b, p.20) SDG&E projects that the units could remain operating without new steam generators through May 2012 (Unit 2) and January 2018 (Unit 3), with an 87% chance that Unit 2 could operate past 2009 and a 97% chance that Unit 3 could operate past 2010. (SDG&E 2005a, pp. 31-34)

SCE has already contracted with a manufacturer to fabricate the eight steam generators and will be obligated for about $50 million of work that will be completed by September 2005, regardless of whether the project obtains final approval. (SCE 2005b, p.25)

SDG&E and the City of Anaheim, two of SONGS' four co-owners, have elected not to participate in the steam generator replacement project.[22] SDG&E, currently a 20% owner, explained that it is unwilling to bear the risk of cost-overruns associated with this project:

> SDG&E is not proposing that SONGS be shut down. The risk that Edison is unable, however, to manage the capital and O&M costs for the SGRP within its "high cost" scenarios is too great for SDG&E to accept. (SDG&E 2005a, p.42)

Under the terms of their ownership agreements, co-owners may elect to reduce their ownership shares in lieu of paying their shares of major capital projects. The City of Anaheim will lose its full 3.16% share, and SDG&E will lose up to its full 20% share. An arbitration board determined in February that SDG&E should lose its full share as long as costs are not significantly lower than anticipated. (SDG&E v. SCE 2005) However, SDG&E maintains that it should retain 12.6-18.6% ownership. The CPUC is reviewing

[21] PG&E hopes to obtain NRC approval to extend Unit 1's operating license by three years, because the current license runs forty years from the date that the low power testing license was issued, rather than the full power operating license. This is known as license recapture.

[22] The City of Riverside will participate in the project and retain its 1.79% share of SONGS.

the case. (CPUC 2004d) NRC approval is also required prior to ownership transfer. (Sempra 2004)

In expressing its concerns over cost-overruns, SDG&E pointed out that the SONGS project is riskier than the Diablo Canyon project:

> SONGS is located on an unusually compact site and was not designed to allow the replacement of the steam generators, which in turn requires Edison to cut large openings in the dome-like containment structures and release of the highly tensioned steel cables that serve to reinforce these structures." (SDG&E 2005a, p.42)

Other intervenors in the case also expressed concerns about the cost-effectiveness of the project.

- California Earth Corps reported that "SCE's analysis is substantially lacking in the following areas: aging components repair and replacement (above and beyond the steam generators themselves), terrorism-related security upgrades, and transportation and environmental mitigation-related costs," with security costs alone estimated at up to $1.4 billion through the end of SONGS' operating license. (CA Earth Corps 2005, p.4)

- TURN again modeled a wide range of scenarios, varying the capacity factor, the replacement energy prices, and the costs of O&M and capital expenditures, and including the possibility of an extended outage or early closure. It found that SGRP benefits were negative in 16 of its 21 scenarios, ranging from negative $1.5 billion to $735 million, and that they will be positive only if the plant exceeds an 84% capacity factor through the end of its license period. (TURN 2004a, Table III)

- ORA concluded that "SCE's proposals to replace the steam generators at Units 2 and 3 are not cost effective when compared to the alternate scenario. The values, on a net present value basis, of the cost effectiveness ratio for SCE's SGRP, [which] range from .57 to .90, are less than 1, which means that the cost of the steam generator replacement project exceeds to benefits of the alternate scenario." ORA recommended that SONGS be shut down and its power be replaced by power imported from out of the state or from elsewhere within the state, including from combined cycle plants, renewables, and conservation. (ORA 2004, p.4)

Some of the intervenors' concerns have been incorporated in the cost analysis below.

Spent Fuel Storage

The federal government is ultimately responsible for disposing of high-level waste from commercial nuclear reactors, and it is has been investigating Yucca Mountain in Nevada as a possible site for a facility. However, until the suitability of this or another site is established and a permanent disposal facility is completed, the utilities are responsible for temporarily storing the spent fuel that their reactors generate. Under the Nuclear

Waste Policy Act of 1982, the federal government was to have begun disposing of the waste by January 31, 1998 (42 USC, 10222), but the government missed this deadline and is still not accepting any waste. The utilities continue to build temporary storage facilities (known as Interim – or Independent - Spent Fuel Storage Installations or ISFSIs) to accommodate additional waste until a federal facility is prepared to receive it.

Diablo Canyon

PG&E's current facilities have ample capacity to store spent fuel produced from Diablo Canyon through approximately 2007 (including the requirement for full unloading of the core, which is an NRC safety requirement.) Under PG&E's contract with the Department of Energy, however, even if a federal waste facility is completed by 2010, the earliest that Diablo Canyon's spent fuel will be accepted for storage or disposal will be 2018. PG&E is seeking approval to build additional storage capacity to prevent a premature shutdown of the plant due to insufficient storage space. It estimates the cost of the ISFSI facility to be $140 million through 2025 and an additional $115 million through 2040. Costs incurred during this second period will be paid from decommissioning funds. (PG&E 2002, p.4)

In March 2004, PG&E received authorization from the NRC to build an on-site dry cask storage facility, which would provide enough space to store spent fuel through approximately 2021 (Unit 1) and 2025 (Unit 2). Mothers for Peace and the California Attorney General etc. appealed that authorization in the U.S. Court of Appeals for the Ninth Circuit, arguing that the NRC approved this project "without allowing full evidentiary hearings on the impacts of terrorism or other acts of malice or insanity against the facility." (MFP 2004a) A decision is expected in the second half of 2005. (PG&E 2005b, p.63)

PG&E has also requested authorization from the NRC to install a temporary storage rack in each unit's existing spent fuel storage pool. This option, which will be used if the dry cask storage facility project is delayed, will provide enough storage capacity only through 2010 (Unit 1) and 2011 (Unit 2). (PG&E 2005b, p.63)

SONGS/Palo Verde

SCE is currently in the process of constructing an ISFSI to store spent fuel from the three SONGS units.[23] The utility has been transferring SONGS 1 spent fuel out of SONGS 2 and SONGS 3 spent fuel pools to the completed ISFSI modules in order to open up more space for spent fuel from the active units, but these pools will still be sufficient to accommodate waste and maintain full core off-load capability only through mid-2007 (Unit 2) and mid-2008 (Unit 3). (SCE 2005b, p.165) SCE received a Coastal Zone Use Permit from the California Coastal Commission to build additional ISFSI modules in

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[23] Information about SONG's fuel storage was obtained from SCE's 2004 annual report and its 2006 GRC application (filed in February 2005). SCE stated that "SONGS 2 & 3 spent fuel pools will run out of space in July 2007 and March 2008, respectively." (SCE 2005a, p.26) A statement in Sempra's 2004 10-k appears to contradict this statement. It says that "spent fuel from SONGS is being stored on site, where storage capacity is expected to be adequate at least through 2022, the expiration date of the NRC operating license." (Sempra 2005)

2001, and the utility expects to receive NRC approval in July 2005. It plans to construct an additional 75 modules built in three phases for a total cost of about $162.7 million, with 2004-2008 costs averaging $14.4 million/year. (CCC 2001a; SCE 2005a)

APS, the operator of the Palo Verde Nuclear Generating Station, has already constructed a dry cask storage facility to store Palo Verde's spent fuel. (SCE 2005b, p.91) It expects to have sufficient space to store the plant's spent fuel through the end of its operating license. (PWCC 2005, p.71)

Reactor Vessel Head And Heater Sleeve Degradation

Reactor vessel head degradation is a widespread problem among nuclear plants. The NRC has ordered upgraded inspections of these heads to identify any stress corrosion cracking. PG&E plans to replace the reactor vessel heads at Diablo Canyon between 2007 and 2009 at a cost of about $67 million. (PG&E 2004b, 5A-23) SCE found and repaired degradation of Unit 3's reactor vessel head in the last quarter of 2004 and plans to replace all of SONGS' remaining reactor vessel heads during the 2009-2010 outages.

SONGS' heater sleeves are made of the same material as its steam generators, and SCE had planned to replace them during the 2006 outage. However, Unit 3's sleeves have already begun to degrade, so SCE replaced 29 out of 30 of them during the 2004 outage, which extended the outage from 55 to 92 days. SCE will replace both units' remaining sleeves and Unit 3's instrument nozzle in 2005 at a total sleeve replacement cost of $17.9 million. (SCE 2005a, p.78)

Additional Security Costs

Security costs at nuclear power plants are guided by an NRC-issued design basis threat, which is the largest threat that a plant licensee is required to design against. On April 29, 2003, the NRC revised the design basis threat for nuclear power plants. Public Citizen and Mothers for Peace sued the NRC for not holding public hearings before issuing this revision. On September 17, 2004, the U.S. Court of Appeals for D.C. issued an order requiring the NRC to establish a proceeding to consider revisions to this design basis threat. (CPUC 2005a, p.18; Public Citizen 2004)

In 2004, SCE spent $54 million in security upgrades required by the NRC's 2003 design basis threat update. (SCE 2005b) SCE and PG&E have estimated that continued compliance with this design basis threat will increase their annual costs by about $5.65 million and $5 million, respectively. (CPUC 2004a, p.44; PG&E 2004b, 5A-15) These figures may increase if a revised design basis threat is issued. Mothers for Peace estimated that PG&E's security costs could increase by up to $365 million in one-time costs, $13 million per year in capital costs, and $54.5 million per year in O&M costs, for a total of $1.4 billion over 15 years. (MFP 2004c, p. 10 Table A, p.13 Table D) California Earth Corps estimated that SCE's security costs could likewise increase by up to $1.4 billion. (CA Earth Corps 2005)

Costs To Maintain Existing Plants

This section develops the going-forward cost analyses for Diablo Canyon and SONGS that estimate the incremental costs of continuing to operate these plants rather than shutting them down in 2005. The analysis excludes all costs that have already been paid or obligated. It is based in large part on cost estimates presented in the steam generator replacement project proceedings. As that project has not yet been approved, cost estimates are provided both for scenarios in which the steam generators are not replaced and the plants close early and for scenarios in which the steam generators are replaced and the plants continue to operate through the end of their licenses. Bounding estimates are provided based on estimates of the utilities, intervenors, and, where available, the CPUC.

Cost estimates are developed for capital expenditures and O&M costs. These estimates are then used to estimate the revenue requirements of each plant. This revenue requirement figure represents the cost to ratepayers to keep the plants operating from January 2005 through the end of their operating licenses.

Capital Expenditures

As part of the SGRP proceedings, PG&E and SCE each presented estimates of the costs to run and maintain their nuclear plants with and without the steam generator replacement. In each case, several intervenors disputed the utilities' projections and recommended they be increased. In PG&E's case, the CPUC adjudicated between the parties as part of its decision to grant PG&E an interim approval. (CPUC 2005c) The CPUC is not expected to rule on SCE's application until September.

Diablo Canyon

Figure 14 presents PG&E's, the CPUC's and intervenors' estimates of Diablo Canyon's capital costs if the steam generator replacement projects are approved.[24] The three estimates represent low, base, and high cases with no case representing a worst-case scenario.[25] The PG&E and CPUC cases differ only in their projection of capital costs beyond 2015. Neither includes any costs for additional security projects that will likely be required if the NRC upgrades its design basis standards, which are currently under reconsideration. The intervenor case presumes that the NRC upgrade requirement takes effect in 2007, requiring significant one-time expenditures in 2008 and 2009 and lower-level ongoing expenditures. All cases include increased expenditures between 2005 and 2009 for the steam generator replacements.

[24] The intervenor case is a compilation of recommendations of TURN, Aglet, and Mothers for Peace.

[25] The costs of possible seismic upgrades, accidents at the plant or other U.S. nuclear plants, and extended outages were not included.

Figure 14: Projected Capital Costs at Diablo Canyon with SGRP

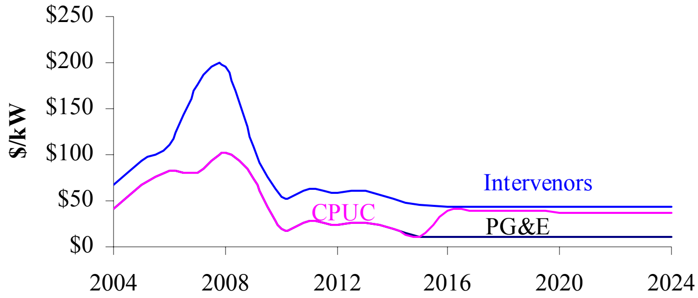
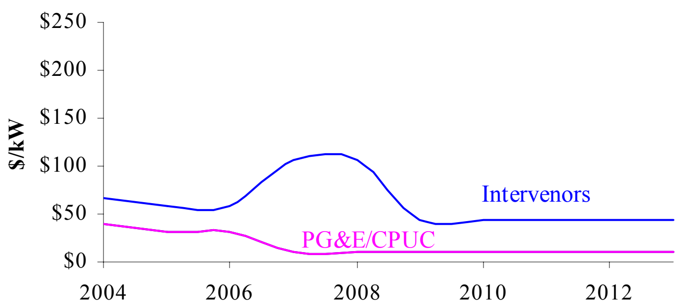


Figure 15 presents the projected Diablo Canyon capital expenditures if the steam generator projects are not approved and the plant closes down in 2013.[26] In this case, the major expense of the steam generator project and certain other capital projects are averted, and there is no difference between PG&E and the CPUC's projections. The intervenors' projections remain higher due to their expectations of higher security-related costs.

Figure 15: Projected Capital Costs at Diablo Canyon without SGRP



SONGS

In the SONGS SGRP proceeding, intervenors similarly argued that SCE's cost projections underestimated the likely true future capital costs for the plant. San Diego Gas & Electric presented historic data showing how SCE's budget forecasts for SONGS underestimated actual expenditures by an average of 571% in the years before Incremental Cost Incentive Pricing was initiated and continue to underestimate actual costs today. (SDG&E 2005a) Actual 2004 expenditures, for instance, were over 3.5 times their forecasted value. The SDG&E case in Figure 16 and Figure 17 modify SCE's

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[26] It is unknown at this time precisely when the plant would be taken offline if the SGRP is not approved. PG&E's estimate in this proceeding was 2013.

projected costs to account for this underestimate using the difference between 2004 estimated and actual costs. This scenario was created out of the discussion presented by SDG&E and was not formally presented by SDG&E as a cost scenario. The intervenors case includes additional security costs and sets capital costs 50% higher than SCE's projection.[27] It does not include the $630 million in unplanned outage costs estimated by California Earth Corps. None of the scenarios account for the cost of marine mitigation projects, which are expected to peak at $24 million in 2006 and drop to $2.4 million in 2008. (SCE 2005d)

Figure 16: Projected Capital Costs at SONGS with SGRP

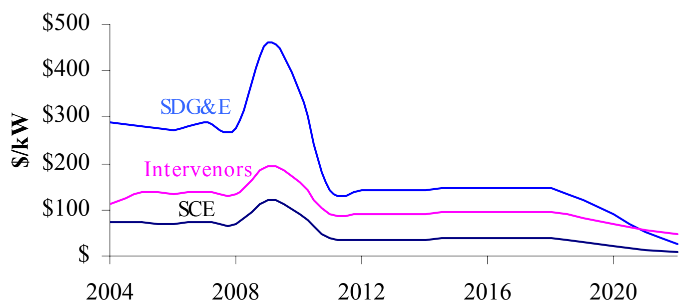
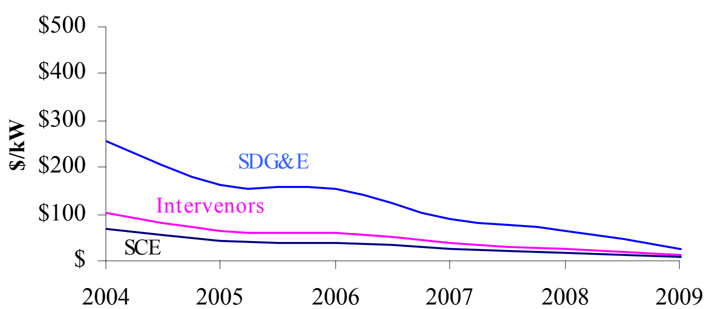


Figure 17 presents projected SONGS capital expenditures if the steam generator project is not approved. In this scenario, all capital projects are expected to be completed by the end of 2009 in preparation for the plant's shutdown in 2010.

Figure 17: Projected Capital Costs at SONGS without SGRP



Non-Fuel O&M Costs

Diablo Canyon

Figure 18 and Figure 19 present the projected O&M expenditures at Diablo Canyon with and without the steam generator replacement project. PG&E's projection is essentially flat over the years, except for increased expenditures in years with two refueling outages.

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[27] Intervenors include TURN, Aglet, SDG&E, and California Earth Corps.

The CPUC case presumes 2.5% annual real escalation in O&M costs starting in 2011. The intervenors case adds the cost of security projects and administration and general (A&G) expenses to the CPUC case.

Figure 18: Projected O&M Expenditures at Diablo Canyon with SGRP

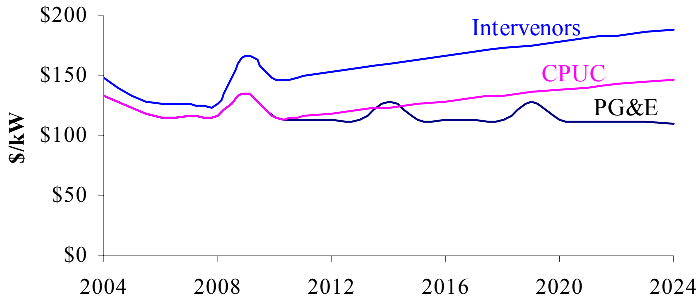
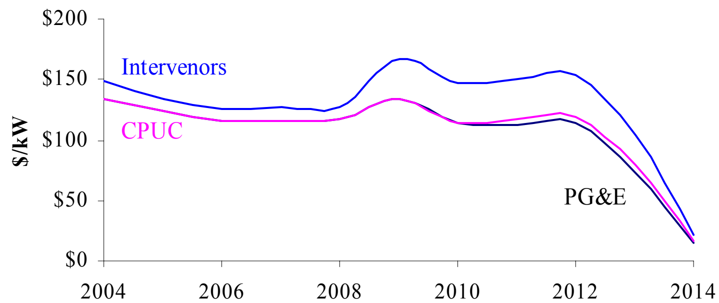


Figure 19: Projected O&M Expenditures at Diablo Canyon without SGRP



SONGS

Figure 20 and 21 present projections of SONGS' O&M expenditures with and without the steam generator replacement project. The intervenor case follows TURN's proposal to increase SCE's estimates by 20% to account for possible SCE cost underestimation (TURN 2004b) and SDG&E's proposal to increase SCE's estimates by an additional14% to account for A&G expenses that had not been included. (SDG&E 2005b)

Figure 20: Projected O&M Expenditures at SONGS with SGRP

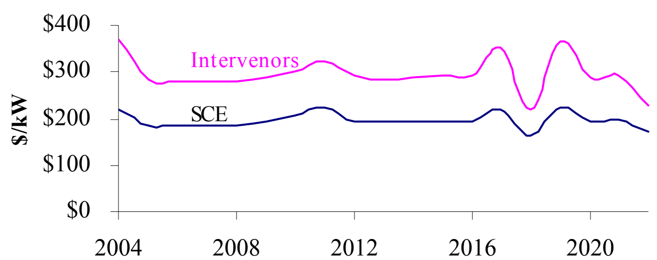
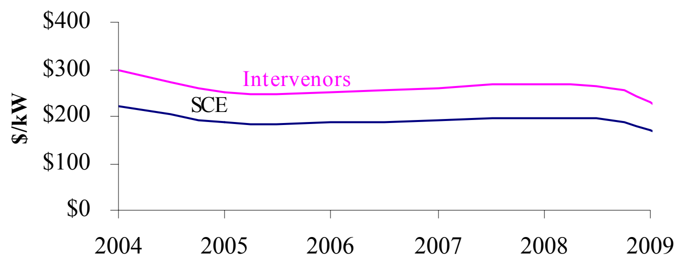


Figure 21: Projected O&M Expenditures at SONGS without SGRP



Nuclear Fuel Supply

Diablo Canyon

PG&E's nuclear fuel costs fell significantly from the early days of Diablo Canyon, when costs averaged $11.85/MWh, through the early 1990's, when they began to stabilize at around $5/MWh. Over the last five years, nuclear fuel costs averaged $5.15/MWh or $86 million per year. (PG&E 1985-2004) In its 2004 annual report, PG&E projected that these costs would increase, as most of Diablo Canyon's fuel supply contracts expired at the end of 2004. New contracts will be subject to tariffs of up to 8% that are imposed on imports from some countries and will reflect higher prices that result from an increased U.S. demand for uranium. (PG&E 2005b, p.67) PG&E's fuel cost estimates in the SGRP proceeding appear not to have taken this increase into account. The CPUC/intervenor scenario (Figure 22), which applies a 4.5% nominal escalation to 2011 fuel costs, takes into account some of this risk.

Figure 22: Diablo Canyon Nuclear Fuel Costs

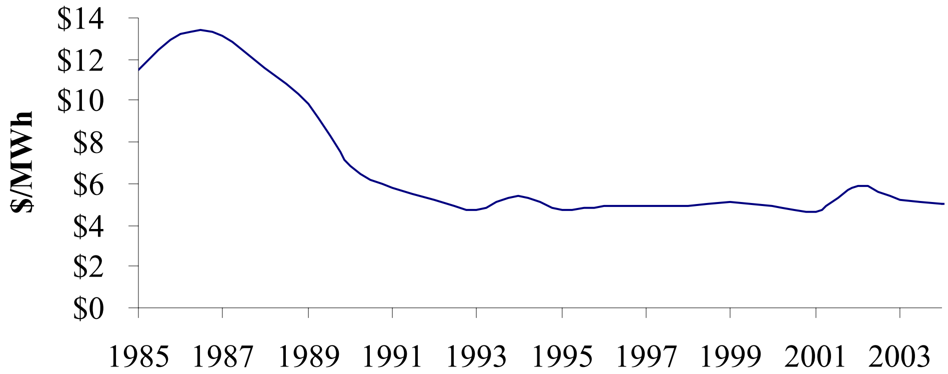
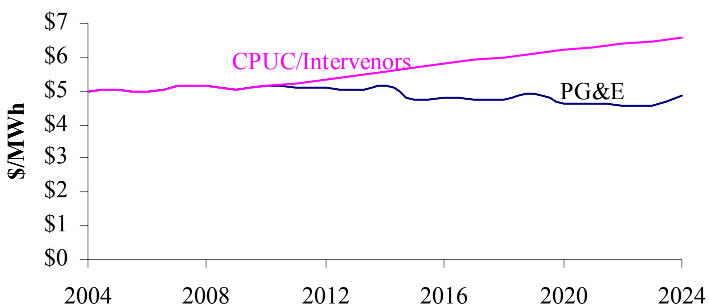


Figure 23: Projected Nuclear Fuel Costs at Diablo Canyon



SONGS

SONGS' nuclear fuel costs have been consistently higher than Diablo Canyon's over the lifetime of the plants, averaging $21/kWh from 1984-1988, $10.62/kWh during the 1990's, and $6.91/kWh over the last five years. SCE spent close to $80 million for nuclear fuel in 2004 and expects costs to remain relatively flat through the end of SONGS' operating license. It has contracts for all of SONGS' fuel through 2008. (SCE 2004, p. 47) Fuel costs were not explicitly discussed by intervenors in the steam generator replacement case. The intervenor scenario below was constructed by applying the 20% increase that was applied to SCE's other O&M cost projections to its fuel cost projections beginning in 2009 when new contracts will come into effect.

Figure 24: SONGS Nuclear Fuel Costs

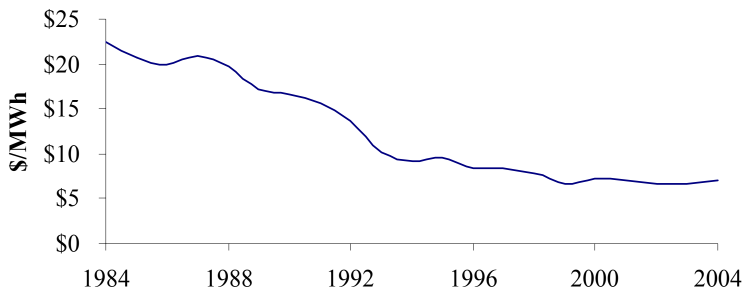
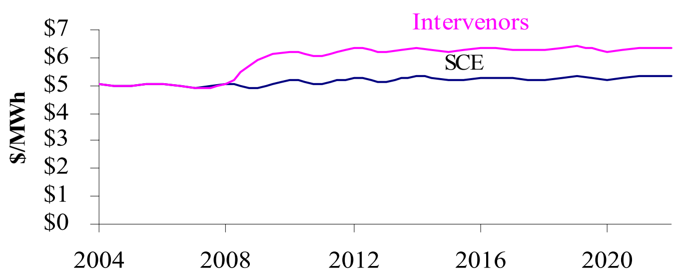


Figure 25: Projected Nuclear Fuel Costs at SONGS



Total Revenue Requirements

The expenses forecasted above include only the projects' direct costs. The amount that the utilities are eligible to recover from ratepayers for these projects (i.e., the revenue requirements) also includes associated taxes, depreciation, and the utilities' return. These costs have been estimated in Table 11 and Table 12. The results show the total expected costs to continue operating the plants from 2005 through the end of each unit's license or, in the scenario where the steam generator replacement is not completed ("Without SGR"), until the unit's premature shutdown.

Table 11: Diablo Canyon Revenue Requirements
(millions)

	With SGR	Without SGR
PG&E	$5,730	$2,851
CPUC	$6,365	$2,883
Intervenors	$8,443	$4,349

Table 12: SONGS Revenue Requirements
(millions)

	With SGR	Without SGR
SCE	$7,355	$3,021
SDG&E	$11,675	$3,948
Intervenors	$14,951	$4,782

All of the Diablo Canyon scenarios were modeled using an 8.6% discount rate, 90.6% average capacity factor, and a 2013-2014 closure in the event that the steam generators are not replaced. They include major capital and O&M projects, such as the replacement of reactor vessel heads and the building of an ISFSI, but they do not include the costs of decommissioning or other sunk costs. Major differences between the scenarios are shown in Table 13.

Table 13: Diablo Canyon Cost Inputs

	Base Capital Costs	SGRP Costs	2011-2024 O&M Costs	Additional NRC Security Requirement Costs	Seismic Projects or Extended Outage
PG&E	$24 million/year	$706 million	flat	Not included	Not included
CPUC	$24 million/year through 2015; $87 million/year from 2016-2024	$706 million	2% real escalation	Not included	Not included
Intervenors	$87 million/year	$847 million (20% higher than PG&E's estimate)	2% real escalation plus $25 million/year in A&G expenses	$1.4 billion over the period 2007-2024	Not included

All of the SONGS scenarios were modeled using an 8.6% discount rate, 88% average capacity factor, and a 2009-2010 closure in the event that the steam generators are not replaced. Major differences between the scenarios are shown in Table 14.

Table 14: SONGS Cost Inputs

	Capital Costs	SGRP Costs	O&M Costs	Additional NRC Security Requirement Costs	Seismic Projects or Extended Outage
PG&E	2006 General Rate Case (GRC) forecast	$670 million	2006 GRC forecast	Not included	Not included
SDG&E	386% of 2006 GRC forecast	$2.6 billion (386% of SCE's estimate)	N/A	Not included	Not included
Intervenors	150% of 2006 GRC forecast plus 3.5% A&G expenses	$832 million (20% higher than SCE's estimate plus A&G expenses)	120% of 2006 GRC forecast plus 14% A&G expenses	$1.4 billion over the period 2007-2024	Not included

Potential Additional Expenses Not Included In Cost Forecasts

Many expenses were not included in the cost analysis, either because they are sunk costs, they are difficult to quantify, or they are highly uncertain. The expenses discussed in this section range from the likely but difficult to quantify, such as unanticipated capital expenditures and additional labor costs, to the unlikely but potentially expensive, such as accidents occurring at other plants. The possibility of an accident occurring at one of California's plants is not addressed. While such an accident could have serious ramifications for all of California's nuclear plants, it is a highly unlikely event.

Unanticipated Capital Expenditures

One source of uncertainty in future capital costs is the inherent difficulty in predicting unexpected events. Mothers for Peace and California Earth Corps have argued that unexpected capital costs tend to increase in older plants, since older reactor components are more likely to degrade or fail. They have argued that the utilities' figures likely underestimate actual expenses because they do not sufficiently take into account the risk of system failure or the probability of large, unforeseen expenses. They have estimated that each plant has a 39.4% chance of at least one unit having an unplanned outage lasting at least one year by 2022. (CA Earth Corps 2004, p.11; MFP 2004b, p.17) The cost of such an outage would include the costs of replacement power and facility repairs. Total costs would depend on the extent of the repairs required.

Potential Unanticipated Capital Expense: Containment Sump Replacement

A loss of coolant accident (LOCA) occurs when the high-pressure water that cools a reactor escapes from its chamber to a containment sump. When this occurs, an emergency cooling system that pumps replacement water to the reactor from external tanks and from the containment sump is initiated. There is concern that high-pressure water flowing from the reactor to the containment sump during the LOCA may carry with it enough debris to clog the sump's screen, impeding the operations of the emergency cooling system.

The NRC has ordered all pressurized water reactors to evaluate their sumps and flowpaths to ensure compliance with updated sump design basis requirements by September 2005. Corrective actions are to be completed by the end of the first refueling outage that begins after April 1, 2006. (NRC 2004c; NRC 2004d) PG&E and SCE are currently evaluating the susceptibility of their cooling systems to debilitation caused by post-accident debris-blockage and both expect the evaluation to be completed by the September deadline. There is a possibility that one or both of the utilities will be required to modify elements of their reactors' containment sumps as a result of these evaluations.

The cost of replacing a containment sump at one of California's nuclear power plants could be high. FirstEnergy replaced the sump pump at Davis-Besse during that reactor's two-year shutdown for an estimated cost of $2.3 million, excluding replacement power costs. (Beacon Journal 2003)

Aging Nuclear Workforce Expenses

PG&E and SCE are both facing aging workforces at their nuclear power plants and are launching recruiting and training programs for the "next generation of employees." (PG&E 2005b, p.18) Training costs will be substantial, as some of these positions require prolonged apprenticeships. For instance, SCE's test technician apprenticeship program lasts 3 years and has a 33% dropout rate. (SCE 2005e, p.21) These training programs, in PG&E's words, are necessary for "preparing these new team members to lead Diablo Canyon forward as members of the current team begin to retire," and for "instilling new team members with principles developed over 20 years of excellence in nuclear power operations – the foremost of which is that safety and security always come first." (PG&E 2005b, p.18)

In addition to training costs, PG&E and SCE may face higher than usual recruiting costs as certain categories of these positions are expected to be difficult to fill. NRC Commissioner Lyon has reported that "the entire industry faces severe shortfalls, and if a rebirth of new plant construction does occur, there will be increased needs and increased competition for the requisite new staff." (Lyons 2005) In 2000, 400 nuclear specialties positions went vacant for lack of qualified applicants. (NEI 2005b) A study by the Oak Ridge Institute for Science and Education estimates that there are approximately two job openings for each graduate in nuclear engineering and health physics. (Lyons 2005) Moreover, in light of the consolidation in the nuclear power plant industry, PG&E and SCE may be at a competitive disadvantage in recruitment efforts. Indeed, SCE had difficulty filling technician positions in 2001 and 2002 and from mid-2002 through at least mid-2004 was only able to hire nuclear engineers by offering relocation allowances and signing bonuses. SCE spent $4.3 million in 2003 recruiting and training these new workers and $5.6 million through October 2004. It is requesting an additional $5.9 million in its 2006 General Rate Case (GRC) to continue recruiting and training. ORA has objected to this cost allowance, asserting that these costs have already been included in the base and that the pace of retirements should ease up after 2004. (CPUC 2004a, pp. 42-44; ORA 2005, p.6A-6; SCE 2005e, pp.16-25)

Accident At Another U.S. Nuclear Power Plant

If an accident occurs at any U.S. nuclear power plant, PG&E and SCE may each be liable to contribute up to $20 million per year to the recovery effort as part of the industry's mutual insurance coverage. If any utility is unable to contribute its share, taxpayers may be required to shoulder the burden.

PG&E and SCE carry two layers of public liability insurance, as required by the Price-Anderson Act: $300 million in primary insurance and $100.6 million in mutual insurance for each reactor. The mutual insurance is a loss-sharing program among all U.S. utilities owning nuclear reactors. In the event of an accident at any reactor, each of these utilities will be liable to pay up to $100.6 million per reactor in payments of no more than $10 million per year.

The utilities carry insurance for property damage, business interruption losses, and decontamination liability through Nuclear Electric Insurance Limited (NEIL), which is also a mutual insurer. This insurance provides coverage of up to $3.24 billion per incident, with the utilities liable for up to $42.5 million per year (PG&E) and $44 million per year (SCE) for an incident at another plant. (PG&E 2005b, p.140; SCE 2005b, p.92)

These mutual insurance structures might carry the risk that member utilities will renege on their insurance obligations. A 2002 Synapse Energy Economics study reported that at least twenty-five nuclear power plants were owned at the time by limited liability companies. This corporate structure shields the utility holding companies from liabilities arising from the nuclear plant. For instance, if a disaster does occur that obligates the limited liability company to pay extensive fees, the limited liability company could declare bankruptcy and avoid paying many of the fees. The holding company and any affiliate companies would not be liable to contribute. Taxpayers would likely shoulder the costs of any unmet needs. (Schlissel 2002)

Taxpayers might also be liable for damages resulting from acts of terrorism at a nuclear power plant and would certainly be liable for damages resulting from acts of war, which are explicitly excluded from coverage under the Price-Anderson Act. (42 USC, 2014(w)) The Act does not specifically address the status of terrorist activities. The NRC has expressed an opinion that these acts would be covered under Price-Anderson but has also acknowledged that the issue would likely need to be decided by the courts. (Schlissel 2002, p.27) The NEIL insurance that the utilities carry provides up to $3.24 billion in terrorism coverage in addition to the amounts recovered from reinsurance under the Terrorism Risk Insurance Act, which could be up to $100 billion. (NEIL 2005; PG&E 2005b, p.140) If the Terrorism Risk Insurance Act is not extended beyond its current December 31, 2005 expiry, this reinsurance will no long be available.

State and local governments are provided some protection under the Robert T. Stafford Disaster Relief and Emergency Assistance Act. If a nuclear accident is declared an emergency or major disaster by the President, the federal government will provide 75% of the cost of temporary housing for up to 18 months, home repair, temporary mortgage or rental payments and other "unmet needs" of disaster victims. (NRC 2005b)

Decommissioning

Decommissioning is the process of closing down a power plant and decontaminating its site. It is an extended process that should result in the site being safely returned to civilian use. Since most of the decommissioning costs are sunk once the reactor is built and first fired, decommissioning costs have not been included in the going-forward cost study.

Regulatory Overview

NRC

The Nuclear Regulatory Commission regulates the licensing and decommissioning of nuclear facilities. It issues licenses for fixed periods of no longer than 40 years, with the possibility of renewal.[28] Once a facility's license has expired, the NRC oversees the decommissioning process required by federal regulation 10 CFR 50.51(b).

Decommissioning must be completed within 60 years of the termination of a plant's operations.[29] The process begins within two years following permanent shutdown when a post-shutdown decommissioning activities report (PSDAR) is submitted to the NRC. The PSDAR must include plans and a schedule for decommissioning, as well as a cost estimate.

Throughout the decommissioning process the licensee must continue to control and monitor radioactive releases from the plant using the same programs and procedures as when the plant was operating. Radioactive waste removed during decommissioning must be handled, treated and disposed of as described in the NRC regulations as well as the unit's license. NRC regulations 10 CFR Parts 20 and 50 regulate the management, treatment and disposal of radioactive waste streams associated with decommissioning activities. Once dismantlement has been performed and the final radiation survey is completed, the license may be terminated. (NRC 2004b)

CPUC

The CPUC oversees the financial aspects of decommissioning. In Decommissioning Cost Triennial Reviews, it approves the amount a utility must set aside annually during a plant's operation for future decommissioning activities. When a plant is ready to be decommissioned, the utility must request use of these funds from the CPUC.

In decision D.87-05-062, dated May 29, 1987, the CPUC ruled that decommissioning funds should be managed by external investment managers. Each utility created a Nuclear Facilities Decommissioning Master Trust Committee responsible for choosing investment managers to manage the decommissioning funds until they are needed. (CPUC 1987) This decision, along with D.95-07-055, also set limits to allowable investment strategies. (CPUC 1995b) For instance, the Qualified Trust, which holds funds that are eligible for income tax deduction, may invest no more than 50% in equities. The Nonqualified Trust may invest up to 60% in equities.

Other California Agencies

Local and regional agencies are often involved in non-nuclear activities related to decommissioning. For instance,

- The California Coastal Commission (CCC) oversees decommissioning-related activities at Diablo Canyon, SONGS and Humboldt Bay that may impact the coast.

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[28] 10 CFR 54 governs license renewals which may be approved for up to 20 years. The renewal process takes approximately two years. (10 CFR, 54)

[29] In the event that a permanent waste disposal facility is unavailable, this time requirement may be waived.

Activities that might be of concern to the CCC include demolition-related pollution, the impact of additional truck traffic, and land use changes at the site.

- The State Water Quality Control Board regulates waste discharges into receiving waters. (SCE 2005b)
- The Air Pollution Control District regulates direct emission sources
- The Hazardous Materials Management Division oversees the removal of hazardous materials, such as diesel fuel storage tanks, from the nuclear plant site.

California's Experience With Decommissioning Plants

California has four commercial reactors that have been permanently shut down: Humboldt Bay, Ranch Seco, SONGS Unit 1, and GE Vallecitos. California also has four smaller test and/or research reactors shut down: two at General Atomics in San Diego and three General Electric facilities in Northern California.

Humboldt Bay

In July 1988 PG&E began decommissioning the Humboldt nuclear facility. Full decommissioning had been planned for 2015, but in 2003 the CPUC approved an alternate plan to begin in 2006. (CPUC 2003) To meet the early decommissioning schedule, PG&E will construct onsite storage for the plant's spent fuel. Once this dry cask storage system is completed, the plant's spent fuel will be removed from the wet storage pools and the plant will be ready for dismantling. On February 24, 2005 the CPUC authorized PG&E to withdraw $35.9 million funds from the Humboldt Bay Power Plant Unit 3 Nuclear Decommissioning Master Trusts to construct this facility. (CPUC 2005d) These funds will cover the costs of the NRC license review and fabrication, construction and loading of activities of an onsite, dry cask storage system. Early dismantlement and decommissioning could save approximately $5.1 million 2004 dollars per year in avoided O&M costs. (CPUC 2000, p.385)

PG&E is currently involved in litigation with DOE over DOE's failure to construct a national waste repository. This litigation is expected to continue for many years. Should the litigation result in a settlement that compensates PG&E for on-site storage fees, all recovered funds shall be deposited in the HBPP Unit 3 Trust. (CPUC 2005d)

Rancho Seco

SMUD's Rancho Seco nuclear plant was permanently shut down in June 1989, and it began to be dismantled in June 1997. All of the plant's spent fuel has been transferred to the onsite ISFSI and most of the hazardous waste has been removed. SMUD projects that by the end of 2006 the spent fuel pools and all large plant components will be removed, and the buildings will be decontaminated. It expects that by the end of 2008 all final radiological surveys will be completed and the decommissioning process will be complete. (SMUD 2002; NRC)

SMUD plans to keep all of Ranch Seco's major concrete buildings and use them for other utility-related activities such as office buildings and a natural gas-fired power plant. It will ship all low-level radioactive wastes generated during decommissioning to the Utah Envirocare facility for disposal. (NRC 2004b)

Like PG&E, SMUD is currently involved in litigation with the U.S. Government seeking compensation for storage of spent nuclear fuel.

SONGS 1

Initially SONGS Unit 1 was to be decommissioned at the same time as SONGS Unit 2 and Unit 3, which is not expected to begin until at least 2022. However, in 1999, the CPUC determined that decommissioning SONGS 1 earlier would be economical while also having the benefit of allowing for the use of current employees who are familiar with the unit. Thus, decommissioning began in 1999. It is expected to be completed by 2008.

The decommissioning of SONGS 1's spent fuel storage facility will be delayed until Units 2 and 3 are decommissioned. It is expected to be completed by 2026.

As a part of Unit 1's decommissioning process, SCE and SDG&E have attempted to dispose of the Unit's reactor vessel at the Barnwell, S.C. low-level waste facility. In 2003, the two utilities applied for and received permits from the California Coastal Commission to transport the reactor via train to a barge that would transport the reactor vessel to South Carolina. However, the railroad companies expressed concerns that the slow speed of the rail car, necessary due to the diameter and weight of the reactor vessel, would interrupt other commercial transportation. The utilities then applied for and received a permit to move the reactor vessel on a transporter to the barge. (CCC 2003) However, the utilities were again unable to arrange for transport of the reactor vessel. Consequently, the utilities have decided to keep the reactor vessel onsite for the foreseeable future. (CEM 2003; NRC)

Also as part of Unit 1's decommissioning process, SCE has constructed an ISFSI. Previously, spent fuel was stored in water filled pools. The ISFSI was completed in late 2003 and SCE expects to have all of Unit 1's spent fuel transferred to the ISFSI by the summer of 2005. In order to keep enough space in Unit 2 and Unit 3's spent fuel pools, some of the fuel currently stored in these sites will be moved into the ISFSI beginning in late 2006.

Decommissioning SONGS 1 has already cost $360 million. These funds will come from the unit's decommissioning trust fund financed through rates. SCE estimates they will spend another $154 million dollars (2004 dollars) to complete the decommissioning. (SCE 2005b)

Decommissioning Plans For Currently Operating Plants

Reactor Facilities[30]

PG&E is scheduled to begin decommissioning Diablo Canyon Unit 1 in 2021 and to complete the decommissioning in 2040. It is scheduled to begin decommissioning Unit 2 in 2025 and to complete the decommissioning by 2041. (PG&E 2005b) As of 2004, PG&E had accumulated $1.629 billion in decommissioning funds. (PG&E 2005b, p.82) The CPUC determined in the 2002 Nuclear Decommissioning Costs Triennial Proceeding for Diablo Canyon that no additional decommissioning funds are currently necessary for this plant. (CPUC 2003)

SONGS Units 2 and 3 are expected to begin decommissioning as soon as their operating licenses expire in 2022. SCE has been paying approximately $32 million a year to the decommissioning trust that will fund the decommissioning of all of SCE's plants, including its partial ownership of Palo Verde. As of the end of 2004, SCE had accumulated $2.7 billion in this fund. The expected cost of decommissioning SCE's plants is $2.2 billion. (SCE 2005b, p.38)

Interim Fuel Storage Facilities

The interim storage facilities that PG&E and SCE are constructing for the spent fuel at SONGS and Diablo Canyon will also need to be decommissioned. However, until there is a permanent storage repository for the spent fuel, the utilities will need to store the fuel onsite. The continued presence of this fuel onsite will prevent the nuclear facilities from being fully decommissioned. At this time there is no contingency plan for the spent nuclear fuel in case a national storage facility is not approved.

Other Considerations

The costs and benefits discussed above do not encompass all of the issues that may impact California's nuclear fleet. This section identifies financial, regulatory, environmental, and safety issues that are also pertinent to a complete cost-benefit analysis.

Price-Anderson Act

The Price-Anderson Act[31] addresses liability for damages to the general public from nuclear incidents. (Holt 2003) It comprises a three-way agreement between the owners

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[30] A License Termination Plan must be submitted to the NRC within two years of the projected termination of a plant's operating license. NRC requires plants to decontaminate the site within 60 years after a plant is shut down and reactor licensees must fund their decommissioning costs up front.

[31] Section 170 of the Atomic Energy Act of 1954, 42 U.S.C. 2210: The Commission shall, with respect to licenses issued between August 30, 1954, and August 1, 2002, for which it requires financial protection of less than $560,000,000, agree to indemnify and hold harmless the licensee and other persons indemnified, as their interest may appear, from public liability arising from nuclear incidents which is in excess of the level of financial protection required of the licensee. The aggregate indemnity for all persons indemnified in connection with each nuclear incident shall not exceed $500,000,000 excluding costs of investigating and

of nuclear facilities, the federal government, and the public: facility owners are required to hold the maximum available private liability insurance, the federal government is required to provide additional funds to pay claims up to $560 million, and the public is required to indemnify facility owners beyond this coverage.

The Price-Anderson Act set up three levels of insurance: primary insurance, secondary mutual insurance, and federal reinsurance. In 1982, the maximum primary insurance coverage available was $160 million. The secondary mutual insurance, which consists of retrospective payments that all nuclear licensees must pay in the event of an accident at any nuclear facility, was set to a maximum of $5 million per reactor per year. The licensing of the 80th reactor that year raised the mutual insurance pool to $400 million, bringing the total coverage to $560 million. This phased out the federal government's obligation to pay, since the government is liable only for funds beyond those covered by insurers needed to cover combined claims up to $560 million. (NEI 2005d) Currently, private insurance is set at $300 million and retrospective payments are capped at $10 million per reactor per year with a $100.6 million per reactor cap. These policies combine to provide up to $10.8 billion coverage per nuclear incident.[32] [33]

The Price-Anderson Act requires owners of commercial reactors to assume all liability for nuclear damages awarded to the public by the court system up to the maximum amount of available insurance and to waive most of their legal defenses following a severe radioactive release ("extraordinary nuclear occurrence"). Congress is responsible to determine how to provide for damage payments above the cap. Congress retains the right to require generators to contribute to these payments. (Holt 2003)

The indemnity provisions of the Price-Anderson Act initially applied only to facilities that were licensed by August 1, 1967. This indemnity was extended repeatedly. In September 2002, the House-Senate conference committee on H.R. 4 approved a compromise that would have extended indemnification through August 1, 2017. It also would have increased the retrospective payment cap to $94 million per reactor ($15 million per year), with small modular reactors being treated as a single reactor up to a limit of 1,300 megawatts. Congress adjourned without completing action on this measure. In the following session, a one-year extension was passed to cover reactors licensed through December 31, 2003 without any changes to the retrospective payments. (Holt) The act

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settling claims and defending suits for damage: Provided, however, That this amount of indemnity shall be reduced by the amount that the financial protection required shall exceed $60,000,000. Such a contract of indemnification shall cover public liability arising out of or in connection with the licensed activity. With respect to any production or utilization facility for which a construction permit is issued between August 30, 1954, and August 1, 2002,205 the requirements of this subsection shall apply to any license issued for such facility subsequent to August 1, 2002.

[32] There are 106 licensed nuclear reactors in the United States: (104 reactors*$100.6 million) + $300 million = $10.8 billion. This coverage would be paid over ten years. Annual coverage is limited to $1.04 billion, with an additional $300 million available in the first year.

[33] A 5% surcharge may also be imposed on top of these payments, raising the total per-reactor retrospective premium to $105.6 million and total compensation to $11.3 billion.

has not been extended since and is currently expired. Existing reactors remain covered, but a reactor newly licensed in 2004 or later would not be covered. (Holt 2003)

There are several bills currently in Congress that seek to extend indemnification to licenses issued by December 31, 2025. Title V1, Subtitle A of both H.R. 6 and S10, the House and Senate versions of the Energy Policy Act of 2005, comprises the Price-Anderson Amendments Act of 2005. H.R. 6 was passed in the House on April 21st; S10 is still being considered by the Senate. If a compromise energy bill is passed with this Subtitle intact, indemnification will be extended through 2025 and maximum retrospective liability will be increased to $95.8 million per reactor ($15 million per year), with small modular reactors up to 1,300 megawatts treated as a single reactor. H.R. 1640, a similar House energy bill, also contains this Subtitle. S.865, a stand-along Price-Anderson Amendments Act which seeks only to extend the indemnity through 2025, is being considered by the Senate Committee on Environment and Public Works. (Congress)

Terrorism Risk Insurance Act of 2002

On November 26, 2002, Congress enacted the Terrorism Risk Insurance Act as a temporary program of "shared public and private compensation for insured losses resulting from acts of terrorism" through December 31, 2005. The intent of the act was to provide a transitional period to help private insurance markets stabilize and build capacity so that they would be able to offer unsupported property and casualty insurance for terrorism risk, which was excluded from most private policies. (15 USC 6701 b) Under the act, all U.S. property and casualty insurers are required to offer coverage for terrorist attacks, with the federal government liable for 90% of damages above the insurer's deductible. (15 USC 6701 e1a) The combined liability of the government and the insurers is capped at $100 billion per year. Congress is to determine how to deal with any claims in excess of the cap.

There are currently several bills being considered in congress that seek to extend this act through 2007. S.467, the Terrorism Risk Insurance Extension Act of 2005 introduced on February 18, 2005, is being considered by the Senate Committee on Banking, Housing and Urban Affairs. H.R. 1153, the Terrorism Insurance Backstop Extension Act of 2005 introduced on March 8, 2005, is being considered by the House Subcommittee on Capital Markets, Insurance and Government Sponsored Enterprises. (Congress)

If these extensions to the Terrorism Risk Insurance Act are not passed and the act sunsets at the end of 2005, it is likely that either premiums for terrorism risk insurance will increase or damage claims will be capped at a lower limit. The extent of these changes is not known.

Spent Fuel Storage

PG&E, Southern California Edison, and Sacramento Municipal Utility District (SMUD) are among the sixty-six parties that have filed suit against the U.S. government for its failure to accept high-level nuclear waste beginning January 31, 1998, as obligated under the Nuclear Waste Policy Act of 1982 and the Standard Contracts that the utilities executed with DOE. (PG&E 2005a; SCE 2005b, p.91) Under these contracts, California nuclear power plants have contributed $1.12 billion to the federal Nuclear Waste Fund in exchange for DOE's taking possession of their spent fuel and storing it in a federal repository. (NEI) DOE has been delayed in fulfilling its side of the contract, since a federal repository has not yet been constructed, and the utilities have sued for damages. SCE and PG&E's cases have not yet been heard. Recent developments in the SMUD case reveal that these cases offer both the possibility of monetary restitution to the utilities and the risk that the courts will nullify the Standard Contracts, which currently obligate DOE to accept high-level waste from the utilities pending the development of a national waste storage facility.

SMUD filed its claim for partial breach of contract in the U.S. Court of Federal Claims on June 6, 1998, seeking to recover $79 million in damages that it has incurred as a result of the government's delay in accepting this fuel, including the construction of an ISFSI. On January 19, 2005, the court ruled that DOE's failure to accept the fuel constituted a breach of contract and held a trial to determine the damages that resulted from this breach. During this trial, the court became aware of facts that led it to question the viability of the Yucca Mountain project and the Standard Contract. On April 21st, the court ordered DOE and SMUD to show cause as to why the Standard Contract should not be considered void and why SMUD should not be refunded the money it paid into the Nuclear Waste Fund (NWF) in anticipation of a federal nuclear waste repository.[34] (SMUD v. U.S. 2005) In their July 7th responses, both parties requested that their contract not be voided and that the NWF fees not be returned. DOE argued that no restitution would be appropriate. (DOE 2005b) SMUD argued that damage payments would be appropriate but not the reimbursement of the NWF funds, as it remains in SMUD's best interests that DOE retain its obligation to take ownership of its spent fuel. (SMUD 2005)

Possible Implications Of An Accident Occurring At Another Plant

If damage is found at a nuclear reactor, other reactors of the same design may have to shut down to undergo inspections and modifications necessary to ensure that they are not also susceptible to this damage. This occurred in March 2002 when a cavity of about 25 square inches across and 7 inches thick was found by chance in the reactor pressure vessel head at the Ohio Davis-Besse Nuclear Power Station. Had the cavity not been discovered, the reactor would have been at risk for a loss-of-cooling accident. (DOE 2002a)

The NRC immediately responded with Bulletin 2002-01, requiring all owners and operators of pressurized-water nuclear facilities to provide information on their inspection programs. Five months later, it added Bulletin 2002-02, requiring additional information on inspection programs and demanding support for the adequacy of visual-only inspection programs. In October 2003 it instituted Order EA-03-009, requiring beefed up interim inspections for reactor pressure vessel heads. (NRC 2002; NRC)

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[34] SMUD has paid $40 million (excluding interest) into the fund.

As a result of this incident, Davis-Besse was shut down for two years (NRC 2004e) and the reactor vessel heads of other plants underwent extensive inspection programs. No indications of corrosion similar to that found at Davis-Besse were found at other plants. However, small cracks were found on the nozzles of some plants. Consequently, the owners of 29 reactors, including PG&E and SCE, have scheduled replacement of the vessel heads by 2007, at an estimated cost of $25 million each. (NEI 2003)

Accidents occurring at foreign reactors may also have implications on the U.S. nuclear power industry, even if there is not a direct connection to designs used in the U.S. As Stewart Brand wrote in a May 2005 TechnologyReview.com article, "It would take only one more Chernobyl-type event in Russia's older reactors (all too possible, given the poor state of oversight there) to make the nuclear taboo permanent."

Coastal Issues

PG&E and SCE must apply to the regional water control boards and the California Coastal Commission or the appropriate local agency for permits for operations that impact the coastal region, such as the discharge of cooling waters into the ocean and the building of new structures near the coast. If any of these agencies find that proposed operations would negatively impact the region, it can require the utilities to mitigate these impacts or, in an extreme case, it can deny the requested permits.

Following are examples of mitigations that have already been required of PG&E and SCE to counter their nuclear plants' impacts on the coastal zone.

In 1991 and 1993, the California Coastal Commission amended SCE's Coastal Development Permit for SONGS 2&3 to require several marine mitigations. SCE has completed three of these projects: a fish behavioral device to reduce mortality in the cooling water intake system, a fish hatchery, and a Marine Science Education Center. SCE expects to complete the other two projects, wetlands restoration and artificial reef construction, by 2008 at an average cost of $14.4 million per year.

The California Coastal Commission imposed conditions on PG&E and SCE pursuant to their applications to construct independent spent fuel storage facilities. PG&E's conditions address the loss of recreational area that its facility will cause and the geologic safety of its site. They require PG&E to provide and maintain public accessways on Diablo Canyon lands and to monitor and maintain protective devices to ensure that slope movements and coastal erosion do not threaten the project. (CCC 2004b) SCE's conditions require that construction debris that might contribute to increased sediment loading to the coastal waters be covered or contained when it is raining and that all debris be disposed of offsite at the earliest practicable opportunity. They also require the on-site sump to be monitored and maintained to ensure that sediment and debris don't inhibit the sump's ability to remove sediments from stormwater. (CCC 2001a, p.4)

Currently, one focus of mitigation efforts is on reducing the harm to the marine environment from the use of the ocean waters for cooling. The Energy Commission has reported that the withdrawal of large volumes of cooling water (up to 2.5 billion gallons per day at the Diablo Canyon Nuclear Power Plant) affects large quantities of aquatic organisms annually through impingement and entrainment. Species impacted include phytoplankton (tiny, free-floating photosynthetic organisms suspended in the water column), zooplankton (small aquatic animals, including fish eggs and larvae that consume phytoplankton and other zooplankton), fish, crustaceans, shellfish, and many other forms of aquatic life. (Energy Commission 2005b, p.93)

In fact, a recent study of five nearshore fish at Diablo Canyon has found that 10-30% of their larvae have been lost. (Energy Commission 2005b, p.94)

In addition, the warmed cooling waters that the plants discharge into the ocean also impact the marine environment. An 18-year research study found that over ten years, the "3.5 degree C rise in seawater temperature, induced by the thermal discharge of the nearby [Diablo Canyon] power plant resulted in significant community-wide changes to 150 species of marine algae and invertebrates relative to adjacent control areas experiencing natural temperature changes." (Energy Commission 2005b, p.99)

In 2003 PG&E applied to the Central Coast Regional Water Control Board for an extension of its water discharge permit.[35] This permit allows PG&E to discharge cooling water and other waters used for the Diablo Canyon's operations or maintenance into the Pacific Ocean. The Water Control Board instituted a technical workgroup to investigate ways to mitigate these impacts, such as establishing conservation easements in intertidal zones or marine protected areas. (CCRWCB 2004, item 46) The Board has not yet come to agreement on the appropriate mitigations. PG&E's previous water discharge permit had been set to expire several years ago, but this dispute has delayed the approval of the new permit. (CCRWCB 2005; CCC 2005)

In 2004 the EPA established new performance standards of impingement and entrainment impact reductions of 80 to 95 percent and 60 to 90 percent, respectively. (Energy Commission 2005b, p.97) It is expected that future water discharge permit renewals will require additional studies on impingement and entrainment impacts pursuant to these new standards and possibly additional mitigations.

Seismic/Tsunami Issues

The NRC establishes design standards for each nuclear plant that include standards for the largest earthquake and tsunami that the plant must be able to withstand. For example, Diablo Canyon's design "conservatively assumes a tsunami occurs during a combination of the worst tide and storm-induced wave conditions, and uses the worst tsunami ever documented on the California coast. The plant's ability to withstand large waves and the maximum wave height at the intake structure were determined through extensive and detailed scale model wave testing." (NRC 2005e, p.26) The NRC also monitors these safety elements of the plants as part of its inspections. For instance, in its latest inspection of Diablo Canyon, the NRC inspection team raised a question about the peak pressure that could be reached in the cooling water system as a result of a tsunami.

[35] The permit is officially known as a National Pollutant Discharge Elimination System (NPDES) permit.

PG&E responded with preliminary analysis showing that the plant should be able to withstand the anticipated pressures. (NRC 2005e, pp.26-27)

The NRC has exclusive jurisdiction over these issues along with all radiological safety issues at the plants. However, several California agencies have also been concerned with seismic and tsunami hazards at the plants. When PG&E and SCE applied for local permits to build temporary fuel storage facilities, these agencies took the opportunity to consider the safety of the proposed facilities and the surrounding areas in the event of an earthquake or a tsunami.

The Coastal Commission concluded that the designs for these facilities are in fact sufficient to sustain an earthquake or a tsunami. (CCC 2004b, pp.53,57) It concluded that the proposed facility for SONGS "so far exceeds the ground accelerations anticipated from the design basis earthquake that it is reasonable to believe that it will be safe from even a much larger earthquake whose focus is even closer than the design basis earthquake." (CCC 2001a, p.19) In its discussion of SONGS' facility, the Commission also expressed its confidence in the seismic strength of the reactors, which were constructed with much higher standards than the minimum design requirements: "although the design basis earthquake may have been undersized, the plant was engineered with very large margins of safety, and would very likely be able to attain a safe shutdown even given the larger ground accelerations that might occur during a much larger earthquake." (CCC 2001a, p,23; CCC 2004b, pp. 53, 57)

The County of San Luis Obispo, however, was not satisfied with Diablo Canyon's seismic plans, and in April 2004, the County required PG&E to begin updating Diablo Canyon's Long Term Seismic Plan as a condition of being granted a permit to construct its spent fuel storage facility. This update will have no impact on Diablo Canyon's costs unless the NRC incorporates it into Diablo Canyon's seismic design criteria, as the County of San Luis Obispo does not have the authority to require the change. (CPUC 2005a, p. 21) If this does occur, PG&E may have an increase in capital costs to accommodate any required seismic retrofits.

PG&E has also initiated a study to assess how Diablo Canyon and Humboldt Bay would be affected by worst-case scenario tsunamis. A previous study found that a tsunami might generate waves as high as 36 feet above sea level at Diablo Canyon and 42 feet above sea level at Humboldt Bay. Diablo Canyon is located 85 feet above sea level, and its dry cask storage facility will be located 320 feet above sea level. Humboldt Bay is located 12 feet above sea level, and its dry casks will be moved to a site 44 feet above sea level. The December Sumatran tsunami included waves that were over 98 feet high. (Chronicle 2005)

Southern California Edison has no plans for a new study. Previous studies have shown the SONGS site to be vulnerable to waves up to 16 feet tall, while the plant sits 30 feet above sea level. (Chronicle 2005)

CHAPTER 4: WASTE STORAGE AND DISPOSAL

Introduction

As discussed above, California law prohibits the construction of any new nuclear power plants in California until the Energy Commission finds that a demonstrated technology or means for waste disposal exists and has been approved by the authorized agency of the federal government. In 1976 legislation directed the Energy Commission to perform an independent investigation of the nuclear fuel cycle to determine whether the Commission could find that technology to reprocess nuclear fuel rods and/or to dispose of high-level nuclear waste had been demonstrated, approved and was operational. After extensive public hearings, the Energy Commission determined that no technology or process met the required standard. (See "Status of Nuclear Fuel Reprocessing, Spent Fuel Storage and High-level Waste Disposal" (Energy Commission 1978))

The federal Nuclear Waste Policy Act (NWPA) of 1982 was passed in part to address the accumulation of spent nuclear fuel at commercial power reactors. It established procedures by which high-level radioactive waste would be transferred from generators and owners to a federal permanent disposal facility. Under NWPA the federal government is responsible for providing for the permanent disposal of high-level radioactive waste and spent nuclear fuel at the expense of the generators and owners of the waste. (42 USC, 111(a))

A 1987 amendment to NWPA designated Yucca Mountain in Nevada as the single site to be evaluated for a permanent geological repository and required DOE to start taking possession of the spent fuel by 1998. (NRC 1987) With continued delays in the Yucca Mountain approval process, the 1998 deadline has long since passed, resulting in litigation against the federal government.

Because DOE has failed to comply with its mandate to receive the spent fuel by 1998, spent fuel must be retained onsite at nuclear power plants. Spent fuel pools, in which used fuel assemblies are placed in metal racks that are submerged in water, are one type of onsite storage. These spent fuel pools were originally designed to hold only the spent fuel generated during a few years of generation. Unable to ship spent fuel off site, California's reactor operators have "reracked" the pools to denser and denser configurations. There are engineering and safety limitations to such "reracking", so it has been necessary to pursue other storage arrangements, such as on-site dry storage.

An interim fuel storage facility utilizing dry casks is one such alternative arrangement. An interim fuel storage facility has been or will be constructed at the SONGS, Rancho Seco, Humboldt Bay, and Diablo Canyon power plant sites. The facilities are designed to accommodate both the current inventory of spent fuel as well as the spent fuel likely to be produced over the remaining period of each plant's operating license. The extended on-site storage provided by these interim storage facilities will provide a window of time in which DOE can meet its obligation to properly site, design, license and construct a permanent repository.

Spent fuel could also be stored at a central interim fuel storage facility located somewhere other than existing power plant sites until a permanent repository becomes operational. There may be security advantages to storing spent fuel at such a central facility, but there are a variety of trade-offs that need to be considered. In particular, an off-site interim storage facility would require spent fuel to be transported twice – first to the interim storage site, then to a permanent disposal site.

Finally, reprocessing could be used to recycle spent fuel and to separate uranium, plutonium and other high-level waste products, potentially resulting in a more compact nuclear waste product for disposal. However, reprocessing is likely to be more expensive than direct disposal of spent fuel and may pose an increased risk for the proliferation of nuclear weapons. Reprocessing of spent fuel would also represent a significant change in long-standing U.S. policy, which has included a de facto moratorium on reprocessing since the 1970's. (Reprocessing continues to be more common in other countries.)

This chapter will review the current status of DOE's efforts to license and operate a permanent waste repository at Yucca Mountain. It will also provide an overview of the litigation that has resulted from DOE's failure to obtain approval for the Yucca Mountain site and the costs that have been incurred by California's ratepayers in light of the alternate storage arrangements required due to that failure. This chapter then discusses the current status of wet and dry storage facilities at the commercial nuclear power plants in California and discusses the safety and economics of these arrangements. The next section of this chapter discusses the status of proposals to license and operate a centralized interim fuel storage facility in the West and discusses some of the trade-offs between on-site versus centralized approaches to interim storage. Finally, this chapter provides a brief overview of the status of reprocessing technology.

Permanent Federal Repository at Yucca Mountain

Pursuant to the NWPA and amendments to the NWPA, a permanent federal repository has been established as the adopted federal policy for storage and disposal of spent fuel. This chapter first reviews the legal framework, regulatory context, and the history and the current status of the proposed permanent repository at the Yucca Mountain site in Nevada.

Nuclear Waste Policy Act of 1982

The Nuclear Waste Policy Act of 1982 (NWPA) was passed in response to the accumulation of spent nuclear fuels at reactors.[36] It established the procedures by which high-level radioactive waste would be transferred from generators and owners to a federal permanent disposal facility.

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[36] The initial nuclear plants were built when it was anticipated that spent fuel would be reprocessed. However, a reprocessing industry never developed in the United States for both economic and security reasons. Consequently, the generators began to run out of storage space long before their operating licenses were to expire.

Under NWPA the federal government is responsible for providing for the permanent disposal of high-level radioactive waste and spent nuclear fuel at the expense of the generators and owners of the waste.[37] (42 USC) Per the provisions of NWPA, generators and owners store nuclear waste at an interim storage facility until a central, federally operated facility is prepared to receive the waste. Generators must remit a quarterly fee of 0.1 cents per kWh to the federally controlled Nuclear Waste Fund for all power that they generate or have generated. NWPA also mandated a standard waste disposal contract ("Standard Contract") that established waste acceptance criteria, scheduling, responsibilities, fees, and data requirements. (DOE 2005a) Finally, NWPA required the federal government to build a permanent waste repository and begin to accept waste under these contracts beginning no later than January 31, 1998. (42 USC)

The responsibility for evaluating repository sites and ultimately developing and operating a repository fell to DOE. The NRC must grant a license to DOE before DOE can construct and operate the permanent repository.

Site Selection

The NWPA identified nine locations as potential sites for hosting a permanent federal repository for spent nuclear fuel. After preliminary studies, DOE selected three sites for more careful examination: Deaf Smith County, Texas; Hanford, Washington; and Yucca Mountain, Nevada. In 1987 Congress amended the NWPA and directed DOE to pursue only the Yucca Mountain site. (NRC 1987)

The Yucca Mountain site was considered attractive for several reasons. The site is remotely located in a sparsely populated area more than 75 miles from any major urban center. Additionally, Yucca Mountain has an arid climate, a deep water table, and is located in an isolated hydrologic basin. The area was also judged to present manageable levels of seismic activity and a low probability of volcanic activity. (DOE 2002b) However, critics such as the State of Nevada have expressed concerns regarding permeability of the local rock to water flows, seismic risk, and potential volcanic activity over the period during which waste will be stored at the repository.

In February 2002, following a formal recommendation from the Secretary of Energy, President Bush recommended the Yucca Mountain site for approval by the Congress. (Bush 2002; LVRJ 2002a)

The NWPA allows a veto of the President's recommendation by the governor of the host state, but also provided that Congress could override the veto with a simple majority of both the House of Representatives and the Senate. After the President's recommendation to Congress, Nevada's Governor Guinn exercised his veto and stated that Nevada would also contest the project in court. (LVRJ 2002b) The House of Representatives overrode the veto on May 8, 2002 by a vote of 306-117 followed by a

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[37] The NWPA also touched briefly on low-level waste storage, establishing that, in order to obtain a license for low-level waste storage, a generator must provide a bond or other financial arrangement to pay for the site and equipment decontamination that will occur upon the site's closure.

Senate override on a 60-39 vote on July 9, 2002. (LVRJ 2002c) President Bush signed House Joint Resolution 87 on July 23, 2002. (OCRWM 2005a)

As of July 2005, DOE has not submitted an application to the NRC for a license to construct and operate Yucca Mountain. The most recent official pronouncement indicated that a license application would be filed in December 2004. (OCRWM 2005b) DOE officially says that the repository will be open by 2010. However, DOE officials have publicly stated that they are “hoping” for 2012. In its recent budget submission to Congress, DOE showed cost estimates assuming a 2015 opening. Some industry officials have put the opening date closer to 2020. (Nevada 2005) The state of Nevada is adamant that a repository will never be opened at Yucca Mountain.

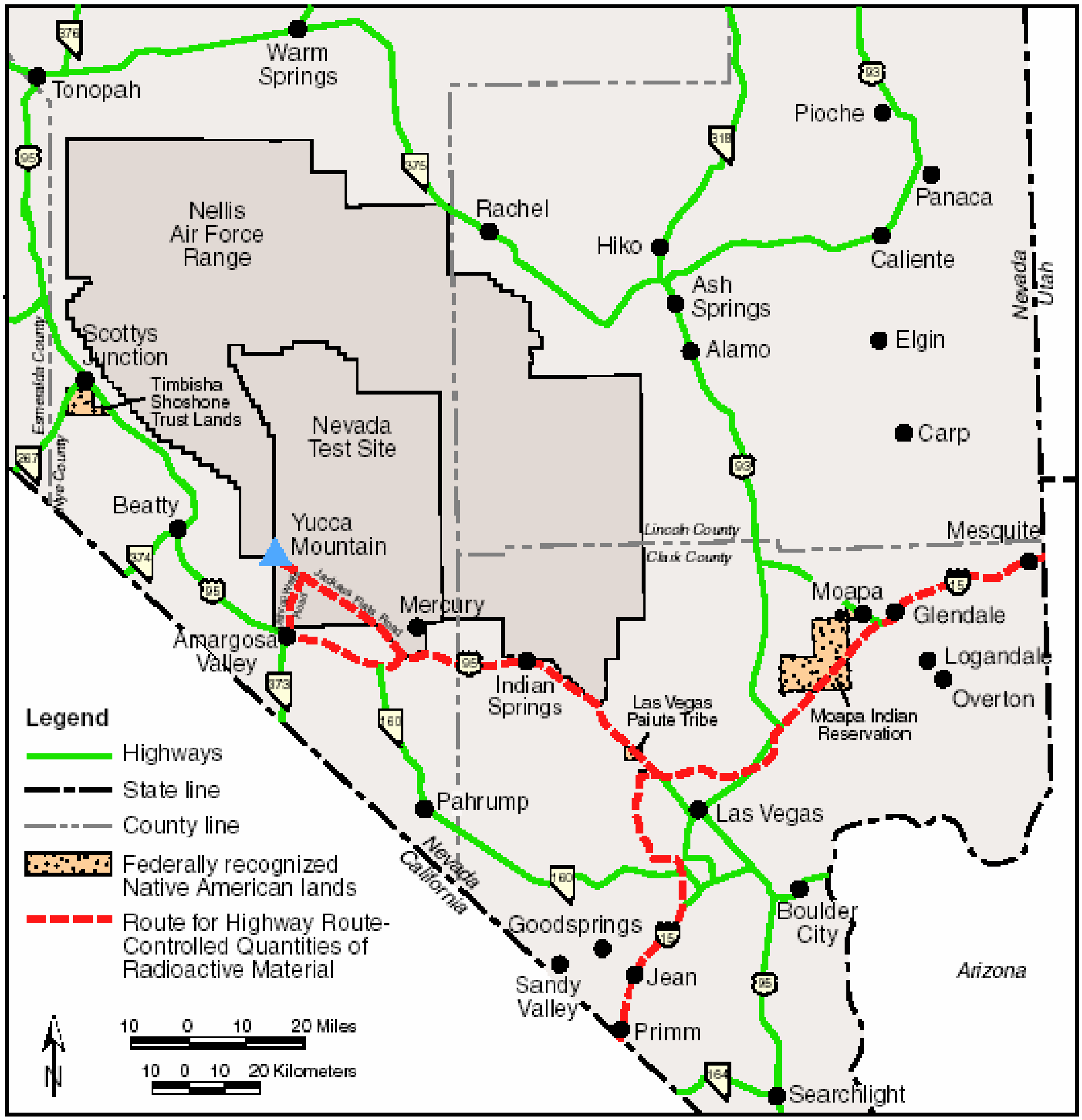
Yucca Mountain: A Timeline

1956:	NAS recommends geologic disposal for spent nuclear fuel
1982:	NWPA initiates site selection process for geologic repository
1987:	NWPA amendment limits site characterization work to Yucca Mountain
1988:	DOE signs Standard Contracts with utilities; agrees to begin accepting spent fuel by 1998
1989:	Site characterization work suspended due to QA problems
1992:	Congress directs NAS to assist in development of radiation standard
1995:	DOE announces it will not begin accepting spent fuel by 1998
1998:	Original deadline passes
2002:	Final Yucca Mountain EIS issued
2002:	DOE authorized to file NRC application to construct Yucca Mountain
2004:	NRC opens pre-licensing application for Yucca Mountain
2004:	D.C. Circuit vacates EPA radiation isolation standard
2005:	Quality Assurance problems resurface with e-mail releases
2007-2010:	Congress to consider need for additional disposal capacity
2010:	Official target date for beginning emplacement activities at Yucca Mountain; DOE has suggested 2012-2015 is more likely
2010:	Begin accepting Humboldt Bay spent fuel; scheduled complete 2012
2010:	Begin accepting SONGS Unit 1 spent fuel
2013:	Begin accepting Rancho Seco spent fuel; scheduled complete 2018
2017:	Begin accepting SONGS Units 2 & 3 spent fuel
2017:	Begin accepting Diablo Canyon Units 1 & 2 spent fuel
2032:	Yucca Mountain construction activities completed
2034:	Emplacement activities complete for high operating temperature option
2060:	Emplacement activities complete for low operating temperature option
2120:	Repository closure for low operating temperature option
2377:	Repository closure for high operating temperature option

Overview of Project

Yucca Mountain is located in a remote area of the Mojave Desert about 100 miles northwest of Las Vegas, Nevada on the western border of the Nevada Test Site (see Figure 26). DOE has been evaluating the suitability of the site for about two decades and has reserved about 150,000 acres for the repository. The proposed area is currently controlled by three government entities: DOE, the Department of Defense and the Department of the Interior. The northern portion of the project lies on the Nellis Air Force Range and the southern portion is on land managed by the Bureau of Land Management.

Figure 26: Yucca Mountain Site



Source: (DOE 2002c)

The actual project will cover only about 1,500 of the 150,000 acres with the remainder of the reserved area serving as a buffer. As proposed, DOE would construct a set of tunnels or drifts at least 660 feet below the surface and at least 530 feet above the water table. The NWPA limits the capacity of Yucca Mountain to 70,000 MTHM of waste.[38] The Yucca Mountain EIS proposed allocating 63,000 of the 70,000 MTHM to commercial spent fuel. The balance (7,000 MTHM) would be reserved for spent fuel from non-commercial reactors and for other high-level waste. DOE estimated that commercial power production and military applications combined could generate 120,000 MTHM of high level waste by 2040. (DOE 2002b)

Approximately 11,000-17,000 sealed containers could be stored at Yucca Mountain. The receiving capacity of Yucca Mountain would be approximately 3,000 MTHM per year, and DOE expects that receiving operations would last at least 24 years, assuming construction of a second repository to take deliveries once Yucca Mountain reaches its mandated storage limit of 70,000 MTHM.

Figure 27: Yucca Mountain

Source: Yucca Mountain Information Office, Eureka County, Nevada

DOE estimates the total cost of constructing the repository at between $42.8 and $57.3 billion. These cost estimates are based on $4.3 billion in waste acceptance costs and the

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[38] The technical capacity at Yucca Mountain may be far higher than this limit. A study by the National Academy of Engineering suggests a potential capacity of 150,000 MTHM and found that the maximum capacity could be "greater by perhaps a factor of two or three." (NAE 2003) The NEI reports that various analyses demonstrate the Yucca Mountain site is physically capable of safely storing between 120,000 and 200,000 MTHM. (DOE 2002b)

balance for construction and operation of the repository. If Yucca Mountain is not constructed and DOE is required to manage 70,000 MTHM of fuel at reactor sites, estimated costs over the first 300 years, i.e., the period leading up to closure of the repository, would be between $167 billion and $184 billion.

In the Final Environmental Impact Study (EIS), DOE considered various closure dates based on a range of temperature and humidity conditions. If the higher operating temperature conditions are adopted, closure of the repository would begin about 76 years after the end of emplacement and last 10 years. If the lower operating temperature conditions are adopted, closure would begin between 125 to 300 years after the completion of emplacement and take between 11 and 17 years.

Legal and Regulatory Impediments

One key event contributing to the delay in the filing of DOE's Yucca Mountain application with the NRC was a July 9, 2004, ruling by the D.C. Circuit Court of Appeals. In 2004 thirteen lawsuits filed by the State of Nevada and several environmental organizations were pending before the D.C. Circuit Court of Appeals. The suits requested that the Court review orders issued by the EPA, DOE and NRC. The July 9, 2004, ruling by a three judge panel resolved these consolidated cases. (NEI v. EPA 2004) The D.C. Circuit Court's ruling contained four main conclusions:

- The 10,000-year compliance period selected by EPA is not "based upon and consistent with" the findings and recommendations of the National Academy of Sciences and therefore violates section 801 of the Energy Policy Act.

- NRC's licensing requirements are neither unlawful nor arbitrary and capricious except to the extent that they incorporate EPA's 10,000-year compliance period.

- Congress had the authority to select the Yucca Mountain site.

- DOE's and the President's actions leading to the selection of the Yucca Mountain site are not reviewable.

Parties opposed to the Yucca Mountain project viewed as a key victory the Court's decision to vacate EPA's proposed rule regarding the compliance period for radiation isolation used in the evaluation of the proposed Yucca Mountain repository. (LVRJ 2004) The EPA now will need to develop a new radiation isolation standard before Yucca Mountain can be licensed. (NEI v. EPA 2004) As a result of these developments, DOE will be required to demonstrate the repository's ability to remain within a maximum radiation dose limit through the period of peak exposure to the environment.

Quality Assurance Issues at Yucca Mountain

There have been significant and persistent concerns over quality assurance issues during DOE's evaluation of Yucca Mountain. NRC requires sufficient quality assurance controls to ensure that all data and other supporting information submitted as part of DOE's Yucca Mountain license application is well documented and verifiable. Ongoing problems with DOE’s quality assurance program have contributed to the delay in DOE’s readiness to file an application with the NRC. (Nevada 2005)

In 1988 a General Accountability Office (GAO) report documented significant deficiencies in DOE’s quality assurance program at Yucca Mountain. (GAO 1988) Problems continued through 1989; as a result, work on site characterization was temporarily suspended. Site characterization work resumed in 1992, but quality assurance problems continued. In the late 1990s, audits performed by DOE revealed that quality assurance deficiencies persisted in three program areas: data sources, validation of scientific models, and software development. By 1999 DOE believed that appropriate measures had been taken to resolve the problems, but similar issues resurfaced again in 2001. (GAO 2003a)

In July 2002 DOE submitted to the NRC a detailed plan to resolve quality assurance issues. As in the past, however, problems persisted. In April 2003, DOE discovered more questionable practices related to data verification. An investigation by DOE determined that “instead of verifying data back to appropriate sources, project scientists had been directed to reclassify the unverified data as ‘assumptions’ which do not require verification.” (GAO 2003a) The release in March 2005 of a series of e-mails written by scientists working on the Yucca Mountain project raised new questions about DOE’s quality assurance program. (LVRJ 2005)

DOE Breach of Contract Litigation

Pursuant to the NWPA, the operators of civilian nuclear facilities entered into Standard Contracts with DOE. The Standard Contract obligated DOE to take possession of, and dispose of, spent nuclear fuel beginning in January 1998. Federal courts have issued several rulings over the past eight years on the interpretation of the contract’s terms as they relate to DOE’s progress, or lack thereof, in developing a geologic repository at Yucca Mountain.

DOE argued that it was not required to assume possession of the utilities’ spent nuclear fuel in January 1998 because the geologic repository necessary to dispose of the spent fuel did not exist. The Federal Appeals Court for the District of Columbia ruled that the existence of a geologic repository was not a condition of the Standard Contract. The utilities had paid 0.1 cents per kWh of nuclear power generated into the Nuclear Waste Fund, thereby fulfilling their obligations under the Standard Contract. DOE therefore had an unconditional responsibility to take possession of the utilities’ spent nuclear fuel in January 1998. The court directed the utilities and DOE to pursue remedies as described in the contract. (IMPC v. USDOE 1996)

DOE subsequently argued that they were not responsible for damages under the terms of the Standard Contract because delays in the completion of the Yucca Mountain project were “unavoidable.” In another key ruling by the Federal Appeals Court for the District of Columbia, the court ruling dismissed this argument, finding that

> Under the Department's interpretation of the governing contractual provisions, however, the government can always absolve itself from bearing the costs of its

> delay if the delay is caused by the government's own acts. This cannot be a valid interpretation, as it would allow the Executive Branch to void an unequivocal obligation imposed by Congress." (NSPC v. DOE 1997)

This ruling paved the way for utilities to file claims to recover monetary damages resulting from DOE's breach of the Standard Contract. As of April 29, 2005, 66 utilities had filed suit against DOE seeking various forms of relief. (Consumers v. USA 2005)

Although the utilities are pursuing monetary damages, the utilities also want to maintain the federal government's responsibility to dispose of their spent nuclear fuel. Therefore, DOE believes that the ultimate resolution will be to open a federal repository at Yucca Mountain and begin to take possession of the utilities' spent nuclear fuel.

One suit for monetary claims against DOE was brought by the Sacramento Municipal Utility District (SMUD) in 1998. SMUD filed a claim for partial breach of the Standard Contract in Federal Claims Court. In the complaint, SMUD states its "claims in this action are for the amounts related to the government's failure to make timely performance. SMUD insists the Government meet its obligation to dispose of SMUD's [spent nuclear fuel]." (SMUD 1998) Rather than requesting a simple voiding of the Standard Contract, SMUD sought both to recover approximately $76 million in damages resulting from costs incurred in constructing an interim storage facility at Rancho Seco and to retain DOE's obligation to accept SMUD's spent nuclear fuel in the future.

The judge issued a key ruling on April 21, 2005, which ordered SMUD and DOE to show cause why the Standard Contract should not be held void and restitution paid to SMUD based on SMUD's contributions to the Nuclear Waste Fund. The ruling also concluded that DOE's claim in December 2004 that a repository at Yucca Mountain would begin accepting spent fuel shipments in 2010 was not credible. Another crucial portion of the Court's ruling stated that "there is no evidence in the record that the Government had reason to believe in 1983, 1989, or at present that…Yucca Mountain ever will be licensed to store spent nuclear fuel and high-level radioactive waste." (SMUD 2005) Both SMUD and DOE agreed that the Standard Contract should not be voided. However, they differed on whether DOE can perform today under the Standard Contract.

Position of the State of Nevada

As discussed above, the state of Nevada is adamant that a repository will never be opened at Yucca Mountain. The state of Nevada raised a number of issues in an *amicus* brief it filed in the SMUD case, including:

- DOE has not yet completed a design or license application for the Yucca Mountain project, nor is DOE currently able to do so. Nevada further asserted that DOE has demonstrated a lack of competence and could not receive a license from the NRC. (Nevada 2005)

- The EPA's 10,000-year radiation standard was invalidated by the D.C. Circuit Court, and a new rule has not yet been developed. Nevada interpreted the D.C. Circuit Court opinion as requiring the EPA to extend its present maximum radiation dose limit though the period of peak exposure determined by the National Academy of Sciences (NAS). Nevada asserted that based on what is presently known about the Yucca Mountain site, the proposed repository could not meet that standard. If the EPA issues a standard that "departs materially from what the D.C. Circuit and the [NAS] required, then Nevada will renew its challenge to the new rule in court."

- DOE has not yet completed the required certification of documents required prior to a license application being submitted. (Nevada 2005)
- Nevada asserted that "given admitted underlying problems with its data, its records, its quality assurance program, and the veracity of its scientists" it is questionable whether DOE can satisfy the NRC's requirements for a "strong safety first culture" and "strict quality assurance regulations."

If and when DOE files an application for certification of the Yucca Mountain project with the NRC, the State of Nevada appears ready to mount a lengthy legal challenge. Nevada has hired a team of "some 30 eminent technical experts" and appears intent on challenging "virtually all aspects of DOE's environmental impact statement for the project." (Nevada 2005) If the Yucca Mountain project obtains a construction license, Nevada suggests that they are prepared to appeal the decision to the full NRC and contest the license in court. Further, Nevada notes that DOE would need to obtain a second permit to emplace waste in the repository. Nevada notes that "this proceeding, too, will be subject to litigation." (Nevada 2005)

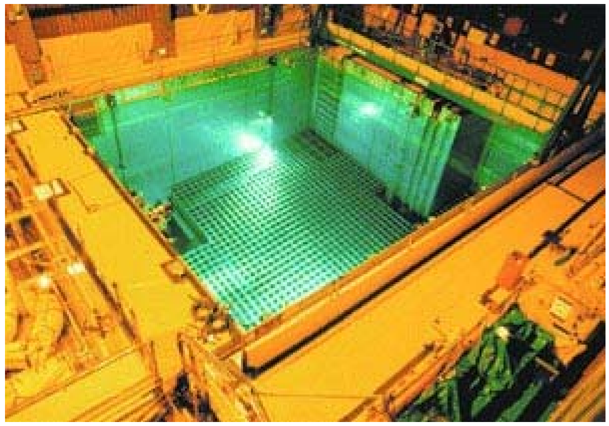
Interim Storage Options

As discussed in the introduction to this chapter, there are two basic approaches to interim storage of spent fuel: wet storage in spent fuel pools or dry storage in storage casks. An interim fuel storage facility containing dry casks can be located either at the site of a commercial nuclear power plant or in a central location to serve a broader region. This section first discusses storage in spent fuel pools and then dry storage in storage casks. Both approaches provide interim storage of spent nuclear fuel to allow commercial nuclear power plants to continue operating pending the opening of a permanent repository.

Wet Storage Facilities or Spent Fuel Pools

There are spent fuel storage facilities at each of the 65 U.S. sites with operating commercial reactors. Figure 28 shows a typical spent fuel pool. During refueling, spent fuel assemblies are transferred from the reactor to the spent fuel pool for storage immediately after discharge from the reactor. (NAS 2005) In addition to providing space for storage of spent fuel, the pools maintain sufficient capacity to accommodate all the fuel in the reactor core in the event of an emergency. This is referred to as full core offload capability (FCOC).

Figure 28: Spent Fuel Pool



Source: (NRC 2005d)

Storing spent nuclear fuel in pools is a well-established practice that has been used for several decades. There have been few significant incidents involving spent fuel pools. However, there are risks involved with wet storage, and it is important to carefully monitor and maintain the water level, temperature, and chemistry of the pool to ensure safe operation. (Harvard 2001)

Safety and Security Issues for Spent Fuel Pools

Safe operation of a spent fuel pool requires that the spent fuel assemblies remain covered by water. The water provides a cooling medium for the fuel, as well as providing a radiation shield to protect workers. Typically, continuous circulation of cooling water is required to keep the temperature in the spent fuel pool below the boiling point of water. More heat is generated in spent fuel pools which contain recently discharged spent fuel assemblies and in which spent fuel assemblies are more densely racked. If the water in the spent fuel pool were to boil off, or be intentionally or accidentally drained, the spent fuel assemblies could heat up and catch fire or melt, potentially releasing harmful levels of radioactive material to the surrounding area.

The chemistry of the spent fuel pool must be closely monitored. After discharge from the reactor, spent fuel assemblies are still undergoing significant radioactive decay. If recently discharged spent fuel assemblies are stored too close together or without adequate shielding, it is possible that their continuing release of neutrons could trigger an unintended nuclear chain reaction. At many reactors, this risk is managed by adding neutron absorbing boron solutions to the pool. As with water temperature, pool chemistry becomes more important in pools where the spent fuel assemblies are more densely racked.[39]

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[39] Considerable care is required to ensure that these arrangements for preventing accidental chain reactions are effective and will remain so. For example, there have been incidents in which panels of

Prior to September 11, 2001, the main safety concerns at spent fuel pools focused on accidents or equipment malfunction. There have been instances in the U.S. where spent fuel pool leaks went undetected for some time. (Harvard 2001) With terrorist attacks a more significant concern, questions have been raised about the ability of spent fuel pools to maintain their integrity in the event of sabotage or attack.

In a 2005 study, the NAS investigated the vulnerability of commercial nuclear plant spent fuel storage facilities to terrorist attack. The NAS concluded that spent fuel storage facilities cannot be ruled out as potential targets, “attacks by knowledgeable terrorists with access to appropriate technical means are possible,” and “under some conditions, a terrorist attack that partially or completely drained a spent fuel pool could lead to a propagating zirconium cladding fire and the release of large quantities of radioactive materials.” (NAS 2005) To reduce the likelihood of a zirconium cladding fire in the event that a spent fuel pool was partially or completely drained, the NAS presented three recommendations:

- Spent fuel stored in pools should be configured such that recently discharged fuel assemblies are stored near older and colder ones, rather than near other recently discharged fuel assemblies.
- Full core offloads should be done infrequently, if possible, and extra security should be provided during these events.
- Redundant systems, such as sprinklers, which could operate even if the spent fuel pool or overlying building were badly damaged, should be installed.

The NAS noted two specific characteristics that would reduce the attractiveness of a spent fuel pool as a potential terrorist target. First, spent fuel pools below grade are less likely to be successfully drained in an attack. The second characteristic cited is an obstructed line of sight to a spent fuel pool from unsecured areas. The NAS also recommended the NRC perform additional studies and analysis, but the NAS committee’s specific recommendations are confidential. The NAS also noted that the NRC’s determination that the NAS committee “did not have a need to know” certain information prevented the study of “several important issues.” (NAS 2005)

There is ongoing debate among other parties about the ability of commercial nuclear plants to defend against terrorist attacks. (GAO 2003b) Most of this debate has focused on spent fuel pools or interim fuel storage facilities rather than the containment vessels. The NRC has expressed confidence that “NRC’s security oversight has been vigilant and has resulted in demonstrable enhancements in the security of the power reactors that have been verified by our inspectors.” (Diaz 2003) However, others question whether the NRC’s Design Basis Threat requirement is sufficiently stringent.

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neutron-absorbing material placed between fuel assemblies have developed large holes, or in which additional water flowed into the cooling pool, diluting its boron content. (Lochbaum 1996)

Another recent study analyzed the conditions that might lead to a spent fuel pool fire and its potential impact. The authors recommend transferring to dry cask storage all spent fuel that has been discharged from a reactor for more than five years. This would reduce the level of Cesium-137 in spent fuel pools and allow a return to open rack storage. This would in turn reduce both the probability and severity of a spent fuel pool fire. (Alvarez et. al. 2003) The authors estimate their recommendation to move to dry cask storage would be cost effective if the probability of a severe spent fuel pool fire was 0.7% over the next 30 years.

Spent Fuel Pools at California Nuclear Power Plants

Spent fuel pools were constructed at each of the four commercial reactor sites in California. Currently, spent fuel is still stored in the wet storage facilities at the Diablo Canyon, SONGS and Humboldt Bay sites. All spent fuel from the wet storage facility at Rancho Seco has been transferred to dry casks, and the spent fuel pool is currently being decommissioned.

Table 15: California Nuclear Reactors: Wet and Dry Storage Data

Plant Name	Core Size	Spent Fuel Pools			Current License Expires	Lose Full Core Offload Capability	Dry Cask Storage?
		Current Capacity	Assemblies Stored*	Remaining Capacity*			
Diablo Canyon 1	193	1324	908	416	2021	2007	Planned
Diablo Canyon 2	193	1317	828	489	2025	2008	Planned
Humboldt Bay	NA	NA	390	NA	Retired	NA	Planned
Palo Verde 1	241	1205	948	257	2024	2004	YES
Palo Verde 2	241	1205	948	257	2025	2003	YES
Palo Verde 3	241	1205	851	354	2027	2003	YES
Rancho Seco	NA	NA	493	NA	Retired	NA	YES
San Onofre 1	NA	NA	665	NA	Retired	NA	YES
San Onofre 2	217	1542	900	642	2022	2007	Planned
San Onofre 3	217	1542	999	543	2022	2008	Planned

Data as of December 31, 2002. (OCRWM 2004)

Diablo Canyon

Each of the two reactors at Diablo Canyon has a dedicated spent fuel storage pool. The spent fuel storage pools and storage racks were initially designed to store 270 spent fuel assemblies for one year before they would be transferred to an offsite reprocessing or disposal facility. PG&E now plans to wait five years before transferring spent fuel from the spent fuel storage pools. (PG&E 2004f) Each Diablo Canyon reactor core includes 193 fuel assemblies. During a typical refueling outage, between 76 and 96 assemblies are replaced, though all the assemblies may be removed from the core as part of the refueling procedure. (Thompson 2002)

Soon after the Diablo Canyon units came on line, it became clear that no offsite storage or reprocessing facility would be available prior to the capacity of the spent fuel pools being reached. In order to continue operation, PG&E needed to expand the capacity of the onsite storage facilities. In 1985 PG&E filed an application with the NRC requesting permission to install a higher density racking system to allow 1,324 fuel assemblies to be stored in each pool. The NRC approved the request. (NRC 1987) The higher density racking system has allowed PG&E to continue to operate Diablo Canyon for the past two decades, but the pools are nearing capacity. PG&E is attempting to address the capacity by constructing a dry cask storage system (see below for a detailed discussion of this proposal). Because the dry cask storage system proposal was challenged by local government agencies, PG&E was forced to seek an interim alternative. In November 2004 PG&E submitted a license amendment request to the NRC requesting permission to insert an additional storage rack in the cask pit area of each spent fuel pool. (PG&E 2004f) If the application is approved, each spent fuel pool would have the capacity to accommodate 1,478 spent fuel assemblies.

At the time of the application, PG&E estimated that, without the addition of the cask pit rack, Unit 1 would lose full core offload capability (FCOC) in 2007 and Unit 2 would lose FCOC in 2008. With the additional storage capacity, PG&E anticipates maintaining FCOC through approximately 2010. (DCISC 2005) The NRC has requested additional information from PG&E and has yet to issue a ruling.

SONGS 2 & 3 Spent Fuel Pools

Each of the two operating reactors at SONGS also has a spent fuel storage pool. The spent fuel pools are similar to those at Diablo Canyon i.e., completely submerged metal racks in reinforced concrete pools. The initial design capacity of the spent fuel pools for SONGS Units 2 & 3 was significantly greater than the Diablo Canyon pools at 800 fuel assemblies each, but was still based on the assumption that spent fuel would be shipped to a commercial reprocessing facility rather than stored onsite through the end of the operating license. (NRC 1990)

In December 1987, SCE applied to the NRC for permission to transfer spent fuel from the pool at Unit 1 to the pools at Unit 2 & 3. There is no spent fuel in the Unit 1 spent fuel pool. (SCE 2005b) By May 2005, SCE had removed all spent fuel from the SONGS Unit 1 spent fuel pool and the pool had been drained as part of the ongoing decommissioning effort.

In 1989, SCE filed a request with the NRC to increase the capacity of the spent fuel pools for SONGS Units 2 & 3 to extend FCOC through fuel cycle 11, beginning in 2001-2002. (NRC 1990) The SONGS 2 and 3 licenses expire in 2022. With construction of dry storage facilities at SONGS (see below), the issue of spent fuel pool capacity appears to have been addressed.

Spent Fuel Pools at California’s Closed Reactor Sites

There are still significant quantities of spent fuel at Humboldt Bay and Rancho Seco. However, wet storage of spent fuel is only currently in use at the Humboldt Bay site. The spent fuel at the Rancho Seco Power Plant has all been transferred to dry storage and spent fuel pool drained. All spent fuel from SONGS 1 is currently either in the spent fuel pool for SONGS Unit 2 or in dry storage at the SONGS site. The spent fuel pool for Unit 1 is empty and has been drained.

Dry Storage Facilities

Both in the U.S. and abroad, placing spent nuclear fuel in dry storage is becoming an increasingly common practice at nuclear utilities. As of December 2004, there were 32 dry storage facilities located nationwide at 25 operating reactors, one decommissioned reactor and six reactors in the process of decommissioning. (NRC 2004a) In the U.S., the NRC issues 20 year operating permits to approved dry storage facilities but has stated that dry storage is "safe and environmentally acceptable for a period of 100 years." (10 CFR 51 1989) A recent study by Harvard University and the University of Tokyo concludes that dry cask storage "is a central element of an optimized nuclear fuel cycle" and that "dry storage potentially provides the flexibility needed for a country to resist being forced into snap policy decisions on spent fuel management." The study characterizes dry storage as an interim solution that provides additional time for countries to consider and develop permanent storage options and not as "a substitute for a permanent approach to the nuclear waste problem." (Harvard 2001)

Safety, Security and Monitoring Considerations for Dry Storage Facilities

When dry casks are designed and fabricated correctly, they are generally regarded as a safe method of storing spent nuclear fuel. Any location which has been licensed for the operation of a reactor should likewise be a suitable location for a dry storage facility. Hence, the main safety considerations with a dry storage facility are that the cask design is sufficiently robust to withstand natural disasters, that it is loaded and sealed properly, and that venting not be obstructed. (Harvard 2001)

In most cases these safety conditions have been met; however, quality control issues have arisen in the past. In the mid-1990s, the NRC investigated some cases of defective cask welding. The defective welds could have led to helium escaping and moist air leaking into the cask. In another instance, some casks were found to have not been manufactured to the licensed design specification. (Harvard 2001) Finally, some minor accidents related to the packing of spent fuel have been reported. In one instance, hydrogen inside a cask was ignited during welding, and the explosion dislodged the cask lid. (Harvard 2001, p.12)

Another concern with the use of dry cask storage is that physical inspections of the spent fuel cannot be performed once the cask has been loaded and sealed. As a result, it is not possible to physically assess whether there has been any degradation in the spent fuel cladding that could lead to contamination risks in the future. It also is not possible to physically count the fuel rods to ensure that none are missing, which creates a potential proliferation threat. Currently this threat is monitored by the IAEA by installing two seals on each cask, so that in the event that one fails, it is still possible to determine if the cask has not been breached. (Harvard 2001)

As with the spent fuel pools, terrorism related safety concerns have been raised since the September 11, 2001 attacks. Robert Alvarez of the Institute for Policy Studies has called spent fuel pools and dry casks “the ultimate dirty bombs” and contends that current waste storage procedures are not safe from terrorist treats. Tests conducted by the NRC have shown that the casks can be punctured with shoulder fired missiles. Such an event might lead to some radiation release. Some have called for dry storage facilities to be constructed in hardened bunkers. (Thompson 2003)

When Germany decided to establish large away-from-reactor spent-fuel storage facilities, it rejected large spent-fuel storage pools and decided instead on dry storage in thick-walled cast-iron casks cooled on the outside by convectively circulating air. The casks are stored inside reinforced-concrete buildings that provide some protection from missiles. (Alvarez et. al. 2003)

Economic Considerations

Dry storage facilities are generally judged to be a cost-effective interim storage solution. Most of the costs associated with the construction of these facilities are upfront costs related to licensing of facility, initial construction of the pad or vault, and the purchase of the casks. There are some additional costs related to the loading and sealing of the casks and some minor costs associated with monitoring and safeguarding them once they are placed on the storage pad. Monitoring and safeguarding costs are likely to be slightly lower at operating facilities than at shutdown or decommissioned facilities because existing personal can simultaneously protect the plant and the casks. Assuming the dry storage facility is in place for 40 years, life cycle costs of dry storage facilities are typically estimated at less than one-tenth of one cent per kWh generated. (Harvard 2001)

The appropriate source of funding for the construction and operation of dry storage facilities in the U.S. is currently in dispute. The NWPA required DOE to assume responsibility for spent nuclear fuel from the nation’s commercial plants in January 1998 and dispose of it in a geologic repository. As discussed above, no geologic repository for the permanent disposal of spent nuclear fuel currently exists. As a result, several utilities have filed suit against DOE seeking damages related to the cost of constructing and operating dry storage facilities.

Interim Fuel Storage Facilities in California

When the quantity of the spent fuel stored began to approach capacity in the re-racked spent fuel pools at Diablo Canyon and SONGS, another fuel storage solution became necessary to continue operating the reactors. The main choices available were to construct new spent fuel pools or place older spent fuel assemblies in dry storage. Both PG&E and SCE filed applications with the NRC for permits to construct dry storage facilities at the existing reactor sites. By the time that PG&E and SCE applied for permits to construct dry storage facilities, or independent spent fuel storage installations (ISFSIs), similar facilities had already been established at several other commercial reactors. Dry storage facility permits were approved by the NRC for both the Diablo Canyon and SONGS sites. PG&E has applied to NRC for approval to construct an ISFSI at its shutdown Humboldt Bay site.

Table 16: Dry Cask Storage at California Power Reactors

Location	Casks	Assemblies	Status
Diablo Canyon	140	4,400	License Approved
Humboldt Bay	5	390	License Pending
Rancho Seco	21	493	Loading Complete
SONGS	104	2,496	Loading Underway

The Sacramento Municipal Utility District (SMUD) has also applied for, and received, a permit for a dry storage facility at the Rancho Seco site. The purpose of SMUD's ISFSI was not to lengthen the operating life of the Rancho Seco reactor, but rather to reduce operating costs related to spent fuel storage and continue the decommissioning process at Rancho Seco. PG&E filed an application in 2003 for permission to construct an ISFSI at its shutdown Humboldt site. (NRC 2005c)

Diablo Canyon

In 2001 PG&E filed with the NRC an application for an ISFSI that would consist of 140 casks with a capacity of 4,400 spent fuel assemblies. The ISFSI would accommodate spent fuel to enable PG&E to operate Diablo Canyon through the end of its license period in 2022. PG&E expects the ISFSI to be constructed in two phases. The first phase will cover the period through 2025 and will consist of 50 casks at a cost of $132 million (2001 dollars). The second phase would cover the period from 2026 through 2040 and would involve placing all spent fuel from the pools in an additional 88 casks.[40] The cost for the second phase is estimated at $107 million. Ongoing costs of the ISFSI are anticipated to be approximately $1.5 million annually. (PG&E 2002) PG&E expects that the casks could be safely stored at the ISFSI for more than 100 years. (PG&E 2002)

The dry storage casks PG&E proposes to use consist of two main components: an external multi-purpose canister, a stainless steel cylinder with neutron absorbing materials, and an internal honeycomb-shaped assembly to accommodate the spent fuel rods. Spent fuel is transferred into the canister while submerged; the whole assembly is then raised from the pool and drained. Once dry, the canister would be backfilled with dry helium, transported to the cask transfer facility, where it would be loaded into a steel and concrete overpack, and then moved to the ISFSI pad for storage.

PG&E also required a coastal development permit from the CCC to construct the ISFSI. While the CCC approved the project in April 2004, that ruling was challenged by local governments in May 2004. (CCC 2004a) The local government's challenge to the ISFSI was related to coastal access issues, since operation of the ISFSI will prevent access to coastal land around Diablo Canyon for much longer than envisioned when the plant was originally constructed. In December 2004, additional conditions were added to the coastal development permit requiring PG&E to provide access to the beach area outside

[40] PG&E plans to fill 138 casks. Two spare casks will also be purchased.

of the high security zone, as well requiring additional geological monitoring to ensure that the ISFSI integrity is not impacted by slope movement or erosion. (CCC 2004a)

On November 21, 2003, the NRC declined to suspend the Diablo Canyon ISFSI licensing proceedings and consider additional security enhancements. In a January 23, 2003, decision, the NRC rejected contentions demanding an environmental impact statement considering the potential effects of terrorism. (NRC 2005f) The NRC had stated that the possibility of a terrorist attack "is speculative and simply too far removed from the natural or expected consequences of agency action to require a study under NEPA." The San Luis Obispo Mothers for Peace filed a petition on December 11, 2003 asking the Ninth Circuit Court of Appeals to review and reverse the NRC's Decisions. The Mothers for Peace contended that the NRC violated the Atomic Energy Act, the National Environmental Policy Act and the Administrative Procedure Act by excluding the consideration of a terrorist attack. (Mothers for Peace 2003)

The Attorneys General of California, Massachusetts, Utah and Washington filed an *Amici Curiae* brief in support of the Mothers for Peace. The brief filed by the AGs requested a secure *in camera* "hearing on the potential environmental impact of acts of terrorism directed against the proposed ISFSI." The AGs specifically wish to present testimony regarding how:

- PG&E might reduce the possibility that the proposed ISFSI will be targeted by terrorists;
- PG&E might reduce the chances of a successful terrorist attack on the proposed ISFSI;
- PG&E might reduce the public health and environmental effects of a successful attack on the proposed ISFSI.

In their petition, the AGs cited numerous statements by the President, the President's Cabinet members, the FBI, the NRC, and the GAO which "demonstrate that federal agencies do, in fact, routinely predict the degree and scope of the risk of terrorism confronting the nation, and particular infrastructure facilities -- including nuclear facilities -- within the nation." The brief also cites the simulated attack scenarios conducted by plant operators and overseen by the NRC as further evidence that the NRC considers the threat of terrorist strikes to be significant. (Attorneys General Brief 2004) A hearing is scheduled for October 17, 2005 in San Francisco. (PACER 2005)

SONGS

In October 2000 SCE proposed building an outdoor storage facility for spent nuclear fuel stored in dry casks. The project, located at SONGS Unit 1, will be constructed in three phases from 2002-2015 and will accommodate approximately 104 concrete fuel storage modules. (SCE 2000)

In addition to NRC approval, SCE also needed to obtain CCC approval before they could begin construction. The CCC review of SCE's proposal focused heavily on seismic issues, including the potential danger posed by earthquakes, tsunamis and landslides. On June 13, 2001, the CCC approved the project with additional conditions. (CCC 2001b) The NRC's evaluation also included a review of seismic issues, concluding that the ISFSI would be safe even in a larger earthquake than the design basis quake for SONGS as a whole. Tsunamis from offshore earthquakes were also considered in the construction of SONGS and found not to pose a hazard for the plant or for the storage facility.

By March 2004 SCE had loaded five casks with SONGS Unit 1 spent fuel which had been stored in the Unit 3 spent fuel pool. After the shutdown of SONGS Unit 1, SCE had transferred spent fuel from SONGS Unit 1 to the spent fuel pools for SONGS Units 2 and 3. SCE has now transferred all SONGS 1 spent fuel stored in each of the three spent fuel pools to the ISFSI and drained the SONGS Unit 1 spent fuel pool. (SCE 2005c)

Rancho Seco

In August 2002 SMUD began emptying the Rancho Seco spent fuel storage pool. Over a period of 16 months SMUD loaded the spent fuel into 21 dry storage canisters. A total of 493 spent fuel assemblies were placed at the ISFSI, including 13 damaged assemblies. SMUD was the first utility in the world to load damaged fuel assemblies in dry storage containers. SMUD expects to save $5 million annually using dry storage compared to maintaining the spent fuel storage pool. (Transnuclear 2002) The decommissioning process is scheduled to be finished by 2008. (NRC 2005c)

Humboldt Bay

PG&E submitted an ISFSI application to the NRC for the remaining spent fuel at Humboldt Bay in December 2003. The Humboldt Bay ISFSI will be unique due to the short length of the Humboldt fuel assemblies. The casks will be stored below-grade to accommodate regional seismic issues, security concerns, and site boundary dose limits. NRC review of the ISFSI application is ongoing. If the application is approved, a decision will then be made on whether to proceed with ISFSI construction.

Decommissioning of the Humboldt Bay plant is scheduled to begin in 2009 and be completed by 2015. (PG&E 2005b) On June 28, 2004, PG&E notified the NRC that it had begun an investigation to determine the storage location of three 18-inch segments of a spent fuel assembly. (PG&E 2004a) On May 31, 2005, PG&E announced that it is most likely that the three 18-inch segments are in the spent fuel pool at Humboldt Bay, but that a conclusive identification is not possible. It is also possible that the segments were shipped off-site. (PG&E 2005c)

Offsite Temporary Spent Fuel Storage

An alternative to storing spent fuel at reactor locations (whether in spent fuel pools or dry casks) is to construct a central temporary storage facility offsite, presumably to serve several reactors. There has been substantial debate regarding the relative merits of constructing dry storage facilities at reactor sites or at centralized off-site facilities. Each has technical and political advantages and disadvantages. (Harvard 2001)

The advantages of away-from-reactor storage include:

- Optimized sites for spent fuel storage, for example farther from major urban centers than power plant sites
- Potential economies of scale in safeguarding stored fuel (Harvard 2001)

The disadvantages of an away-from-reactor storage site include:

- At-reactor storage will still be needed while the power plants operate
- Potential benefits of lower safeguarding costs at a central location are offset the need to maintain at-reactor security as well
- If a central facility is located other than at the ultimate permanent disposal site, the spent fuel will need to be transported twice. (Harvard 2001)

As discussed in the following sections, there have been both federal and private efforts to explore the potential for centralized storage of spent fuel.

Federal Monitored Retrievable Storage

The 1982 Nuclear Waste Policy Act directed DOE to study monitored retrievable storage (MRS) options for managing high-level radioactive waste and spent fuel. The NWPA did not specify whether these MRS facilities were to serve as interim storage prior to transport to a permanent geologic repository or to serve as longer-term, or even permanent, disposal sites in the event that geologic repositories proved infeasible. Recognizing the political controversy surrounding the selection of a permanent repository, and intending to spread the burden of managing nuclear waste, Congress barred MRS facilities from any state under consideration as a permanent repository site.

In 1985 DOE identified the site of the canceled Clinch River Breeder Reactor in Oak Ridge, Tennessee as the location of a proposed MRS facility. The facility was to have a capacity of about 15,000 MTU. Two backup sites were also identified, both located in Tennessee. In selecting the MRS sites, DOE had failed to consult with Tennessee officials who, under the NWPA, had the right to veto the site selection. Tennessee exercised its veto rights and sued DOE for failing to consult with them prior to selecting the site. (Harvard 2001)

Congress again addressed MRS siting in the 1987 amendments to the NWPA, but this time the NWPAA forbade the construction of an MRS until a permanent repository had been issued a construction license. As a result, the Oak Ridge MRS proposal was revoked. The amended act also established an MRS Commission to study the need for interim storage. A 1989 study by the Commission, (MRSRC 1989) concluded that proceeding without interim storage would be marginally less expensive than construction of interim storage. The Commission also proposed a smaller emergency facility of 2,000 MTU and an interim storage facility with a 5,000 MTU capacity to store spent fuel from plants with insufficient on-site storage space or that had ceased operation. The Federal emergency storage facility would be built using funds already collected, while the interim storage facility would be paid for by utilities requiring additional storage. (Harvard 2001)

In the early 1990s, the Nuclear Waste Negotiator solicited interest from communities willing to host an MRS facility in exchange for annual payments of $5 million prior to receiving spent fuel and $10 million per year during operation of the facility. Applications were received from four counties and 20 Native American tribes. None of the county applications proceeded further after their states acted to block their applications. [41] The sovereign status of Native American tribes kept states from vetoing their applications, thus these communities were left as the only viable locations. Two tribes, the Mescalero Apaches in New Mexico and the Skull Valley Goshutes in Utah, moved to a final study stage. Legislative authority for the Office of the Nuclear Waste Negotiator expired in 1995, effectively ending DOE efforts to site a federal MRS facility. (Harvard 2001)

With the failure of the federal government to develop either interim storage or a geologic repository, the industry has focused on expanding on-site storage capacity and private development of interim spent fuel storage facilities.

Private Spent Fuel Storage Facilities

Private Fuel Storage: Skull Valley Reservation, Utah

With the delay in establishing a permanent geologic repository, and faced with increasing storage constraints at reactor sites, a consortium of eight utilities moved to develop a private interim spent fuel storage facility. The consortium formed Private Fuel Storage, LLC (PFS), to pursue this effort. PFS was spearheaded by Northern States Power, which was facing possible early closure of its Prairie Island facility as a result of limitations on dry cask storage at the facility that were put in place by the Minnesota legislature in 1992. (Harvard 2001) Five companies of the original eight companies are still actively involved with PFS:

- Entergy Nuclear Indian Point 2, L.L.C.
- Florida Power and Light Company (subsidiary of FPL Group)
- Genoa FuelTech, Inc. (subsidiary of Dairyland Cooperative)
- Northern States Power Company (Xcel Energy)
- Southern Company

[41] In one case, the county commissioners were removed in a recall election.

Utilities that dropped out of the PFS effort include:

- Indiana Michigan Power Company (subsidiary of American Electric Power)
- FirstEnergy Corporation (merged with GPU) - less than 10 percent interest
- Southern California Edison - less than 10 percent interest (WIEB 2005)

PFS began its search for a host community with parties that had participated in the federal MRS siting process. Efforts to negotiate an agreement with the Mescalero Apache tribe broke down over an ability to reach agreement on economic terms. (Harvard 2001)Additionally, there was pressure from New Mexico, which already was the site of the Waste Isolation Pilot Plant (WIPP) for defense department transuranic wastes. (Environmental Politics 2004) Thus PFS development has focused on the Skull Valley Goshute site in Utah.

Private Fuel Storage (PFS) plans to build a 100-acre interim storage site with 40,000 MTU capacity on the Skull Valley Goshute Indian Reservation in Utah, 40 miles southwest of Salt Lake City. PFS would use above-ground storage casks storing 10 MTHM of spent fuel each. The company will not open any containers on site in an effort to minimize radiation releases. All deliveries to the site would be via rail car. PFS is currently working with the railroad industry to design a rail car to deliver casks to the PFS facility. (PFS 2005)

In 1997 PFS filed an application with the NRC to license the Skull Valley facility. The State of Utah has consistently opposed the facility; at one point Utah's governor sought to seize control of all roads surrounding the Goshute reservation to prevent spent fuel from crossing onto tribal land. (Harvard 2001) In February 2005 the Atomic Safety and Licensing Board (ASLB) ruled in favor of PFS on the last remaining issue, safety in the event of a military airplane crash into the facility. The NRC must now review the ASLB rulings prior to issuing a license to PFS. (PFS 2005) Prior to receiving the first shipment PFS must also receive a right-of-way from the US Bureau of Land Management to build a rail line connecting the facility to the nearest existing rail line (32 miles). As a backup, PFS has proposed building an intermodal transfer facility to transfer casks from rail cars to trucks. (WIEB 2005)

The PFS contract with the Goshutes is for a 25-year lease with a single option to extend for another 25 years. After the lease expires in 2047 PFS must remove all spent nuclear fuel from the property. (Harvard 2001)

NEW Corporation: Owl Creek, Wyoming

In addition to the PFS effort, a private spent fuel storage facility has been proposed by the NEW Corporation for Owl Creek, Wyoming. The Owl Creek Project would be built on a private 100-acre site adjacent to the town of Shoshoni, with storage space for up to 40,000 MTHM of spent fuel. However, Wyoming law prohibits Owl Creek from seeking required legislative approval prior to the filing for an application by DOE for a license to build a federal repository. DOE's failure to apply for a license for Yucca Mountain has delayed the Owl Creek Project. The resulting increased costs and uncertainty over continued project funding have cast doubt onto whether the project will move forward. (Harvard 2001, p.53)

Reprocessing

Reprocessing refers to the recovery of usable plutonium and uranium from fissile waste products. There is currently only one viable method for reprocessing, known as PUREX (Plutonium-Uranium Extraction). It was initially developed as part of nuclear weapons programs, going as far back as the Manhattan Project, to recover plutonium for nuclear bombs. In the 1960s, the process was envisioned to be part of a “closed fuel cycle,” in which plutonium recovered from spent fuel was used in fast breeder reactors. Today, it is used mainly to recycle uranium and create uranium-plutonium mixed-oxide (MOX) fuels to replace a fraction of the standard uranium fuel in some European and Japanese reactors.

Briefly, reprocessing consists of the following steps: the fuel rods are stored for months or years to reduce radioactive decay and heat generation; the non-fuel cladding around the fuel rods is removed; the de-cladded fuel rods are dissolved in nitric acid; and uranium and plutonium are extracted using liquid organic solvents.

The net result of reprocessing is that the original spent fuel is transformed into reprocessed uranium (approximately 95% of the mass of the original fuel material), plutonium (1%), and a nitric acid solution containing the highly radioactive fission products and other isotopes. In addition, a variety of low-level and intermediate-level wastes (LLW and ILW) also result from the process.

In principle, both the reprocessed uranium and plutonium can be recycled into new fuel rods. However, transforming reprocessed uranium into fuel-grade uranium is more expensive than mining and refining fresh uranium fuel. The plutonium can be fabricated into uranium-plutonium mixed-oxide (MOX) fuel, which can then replace about 30% of the standard uranium fuel rods in a reactor. This process, too, is more costly than using fresh uranium, although, as discussed later, the non-proliferation benefits of reusing rather than storing the refined plutonium are seen by some advocates as outweighing the additional cost.

Reprocessing in the U.S.

During the 1960s and 1970s, the United States, along with the other countries processing nuclear power programs, focused on the development of breeder reactors. Programs were launched to reprocess spent light water-reactor fuel to recover the ~1% plutonium it contains for start-up cores for the breeder reactors. (Von Hippel 2001) The driving factor behind breeder reactor development was the perception that uranium supplies were very limited coupled with the perception that a fuel cycle including breeder reactors could extract ten times the energy from the same amount of uranium.

The breeder reactors, upon which the reprocessing programs were based, turned out to be more technically difficult to design and operate and more expensive than anticipated.

In addition to the escalating cost estimates for breeder reactors, nuclear development dramatically slowed in the 1970s while at the same time significant new reserves of uranium were discovered. These two latter factors dramatically lowered the price of uranium, making the expensive breeders even less economically attractive.

Beyond the technical and economic pressures, reconsideration of U.S. policies to promote plutonium-fueled reactors were heightened in 1974, when India tested a nuclear explosive made with plutonium separated with reprocessing technology provided by the United States. (Von Hippel 2001) This brought to a head the debate over non-proliferation, that the projected “global plutonium economy,” in which millions of kilograms of plutonium would be separated out of spent fuel annually, might spawn nuclear terrorism. (Von Hippel 2001)

The reassessment initiated by the Ford administration was completed by the Carter administration, which decided in 1977 against licensing the newly built reprocessing plant in Barnwell, South Carolina. Although this licensing moratorium was later reversed by the Reagan administration, by that time high costs associated with commercial reprocessing meant there was no longer any industrial interest in reprocessing in the United States. In 1993, the Clinton administration reinstated U.S. opposition to reprocessing. During the 1980s and early 1990s, the United States along with Germany, the United Kingdom, and France all abandoned their breeder-reactor demonstration programs. (Von Hippel 2001)

The May 2001 report of the National Energy Policy Development Group, chaired by Vice President Cheney, reopened the question of spent fuel reprocessing by recommending that, "The United States should reexamine its policies to allow for research, development, and deployment of fuel conditioning methods ... that reduce waste streams and enhance proliferation resistance". (NEPDG 2001a) Hearings before Congress to address reprocessing are ongoing.

The first—and only—commercial reprocessing plant in the U.S. was at West Valley, New York, on land owned by the State of New York and leased to the plant operator, Nuclear Fuel Services. (DOE-Ohio 2005) The West Valley plant operated from 1966 through 1972 and accepted radioactive waste for disposal until 1975. During the operation of the plant, 640 MTHM of spent reactor fuel were processed, resulting in 660,000 gallons of highly radioactive liquid waste, which is still stored in an underground waste tank. By 1976, costs and regulatory requirements of reprocessing made the venture impractical and the facility was closed. Four years later, NFS exercised its right to leave the site and transferred ownership and responsibility for the waste and facility to the state of New York, who in turn passed on the liquid high-level waste and decontaminating and decommissioning responsibilities to DOE.

Also in the 1970s, a second reprocessing plant with a capacity of 300 MTHM per year was built at Morris, Illinois, incorporating new technology which, although proven on a pilot-scale, failed to work successfully in the production plant. The third was a 1500 MTHM per year plant at Barnwell, South Carolina, was constructed but never operated, due to the Carter administration policy that ruled out all U.S. civilian reprocessing as one facet of US non-proliferation strategy. (Hore-Lacy 2003)

Reprocessing Issues

Economics

There is substantial consensus, even among nuclear advocates, that reprocessing spent fuel is not currently economic, although the degree to which it is uneconomic is debated. (Harvard 2003) A recent study conducted at MIT noted “closed fuel cycles [which are based on reprocessing] will be more expensive than once-through cycles, until ore resources become very scarce. This is unlikely to happen, even with significant growth in nuclear power, until at least the second half of this century, and probably considerably later still.” (MIT 2003) Another study conducted at Harvard noted that “[t]he data and analyses presented in this report…demonstrate that the margin between the cost of reprocessing and recycling and that of direct disposal is wide, and is likely to persist for many decades to come.” (Harvard 2003)

In hearings held in July 2005, Richard Lester, a researcher at MIT, testified:

> Under current economic conditions, and making generally optimistic assumptions about how much reprocessing and MOX fabrication services would cost were they to be available in the U.S., I estimate that a U.S. nuclear power plant opting to use these services would incur a total nuclear fuel cycle cost of about 1.8 cents per kilowatt hour of electricity. By comparison, the total cost of the once through fuel cycle is a little under 0.6 cents per kilowatt hour. In other words, nuclear power plants operating on the closed fuel cycle would experience a nuclear fuel cycle cost increase of about 300%. (Lester 2005)

At those same hearings, nuclear industry representative Marvin Fertel[42] said that reprocessing holds great promise to address issues such as nuclear fuel supplies and waste disposal, but he said that additional research and development is needed to make reprocessing economically viable. “Future reprocessing of used nuclear fuel is a worthy goal, but it must overcome several challenges before it can be used in the United States.” (Pouliot 2005)

Operations Safety

Given the large inventory of spent fuel being reprocessed and fissile materials handled, safety must be an utmost concern in the design and operation of reprocessing plants. Radioactive materials must be controlled and contained, and fission chain reactions must be prevented.

A footnote in the recent MIT study notes that “A brief comparison of reprocessing plants with reactors shows that the historical accident frequency of reprocessing plants is much larger than reactors... Furthermore, the number of reprocessing plant-years of operation

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[42] Senior Vice President and Chief Nuclear Officer at the Nuclear Energy Institute.

is many fewer that in the case of reactors. Therefore the accident frequency of reprocessing plants is much higher." (MIT 2003)

A notable event at a modern reprocessing facility occurred earlier this year.[43] On May 9, 2005, the press reported that about 20 MTHM of uranium and plutonium dissolved in concentrated nitric acid internally leaked at the Sellafield facility in Great Britain in January 2005, but was only discovered three months later. As the leak occurred in a contained area, no radiation was released. Repairing the pipes and recovering the spilled liquids is expected to take months and may need special robots, which will have to be built. The THORP plant (Thermal Oxide Reprocessing Plant) generates about £1 million [$1.8 million] a day which is used to finance the cleanup of redundant nuclear facilities. (London Times 2005)

The criticality event that occurred in 1999 at the Tokai complex in Japan, in which worker error caused an uncontrolled chain reaction in a solution containing enriched uranium, was not associated with the reprocessing facility. Rather, it was associated with the experimental fast reactor also located on the site. (UIC 2000)

Environmental Impacts

During the course of operation, reprocessing facilities release "small" amounts of radioactivity into the atmosphere or into liquid wastes from the reprocessing plant. These releases have been the focus of local and international environmental groups. Cancer clusters have been alleged around both Sellafield and La Hague in France. (BBC 2002; Guizard 2001) Even if the allegations prove to be true, because both sites have historical and ongoing nuclear activities beyond their current role as reprocessing plants, the links between the cancer clusters and ongoing reprocessing activities would not be clear.

The liquid nitric acid high level nuclear waste (HLW) produced from reprocessing must eventually be solidified (usually by mixing it with molten glass, which is then hardened, a process known as vitrification), and disposed. Reprocessing reduces the volume of HLW relative to direct disposal of spent fuel. However, for spent fuel and HLW, the volume is not necessarily an adequate proxy for their disposal burden. The heat generated by spent fuel and HLW, not the volume, is the major factor in determining the amount of space they would require in a geological repository. The need to space out the spent fuel and HLW means that their effective volume in the repository will be much greater than their actual volume would indicate. Furthermore, reprocessing creates, in the long run, greater volumes of intermediate level waste and significantly greater volumes of low-level waste than directly disposing of the spent fuel. (IEER 2000) This is due to the fact eventually the whole reprocessing facility will have to be treated as low-level waste.

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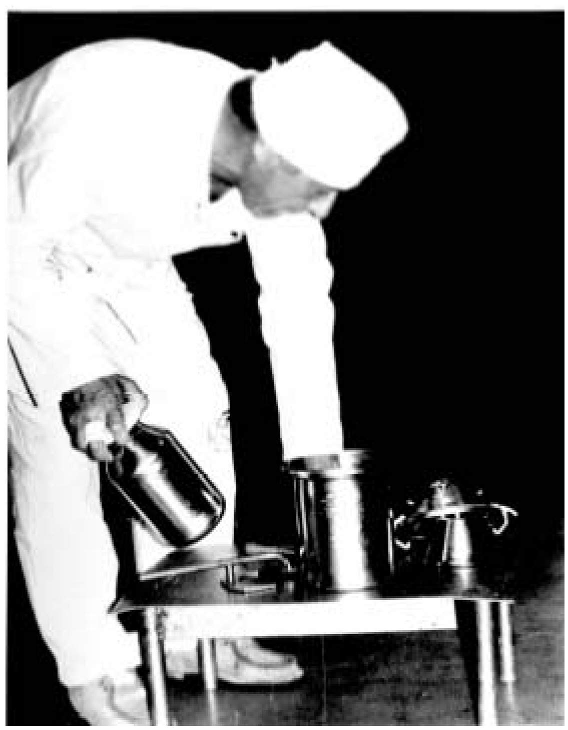
[43] With respect to older reprocessing facilities, in 1957, the Chelyabinsk reprocessing facility in the then Soviet Union suffered one of the worst nuclear disasters on record when a system of a radioactive waste containment unit malfunctioned and exploded. The explosion spewed some 20 million curies of radioactivity into the atmosphere. About two million curies spread throughout the region, exposing 270,000 people to as much radiation as the Chernobyl victims.

Non-Proliferation

The gravest concern, which resulted in the Ford and Carter administrations' decision to halt reprocessing in the United States, is proliferation, i.e., the creation of small volumes of easily transported radioactive materials (plutonium) that could be used to create a nuclear device, either by a terrorist or a nation that would not have the nuclear infrastructure to create plutonium on its own. The American Physical Society noted in a recent paper, "The principal proliferation concern among the various elements of a nuclear power system are the enrichment and reprocessing facilities, which can produce materials directly usable in weapons." (APS 2005)

Although the reprocessing facilities in Sellafield and La Hague maintain tight security and convert the plutonium into MOX on site, only a small volume of plutonium is needed to create a nuclear device: less than 8 kilograms of plutonium is required to make a Nagasaki-type bomb. For example, the canister held by worker pictured below (Figure 29) in Russia's commercial reprocessing complex near Chelyabinsk contains 2.5 kg of plutonium dioxide powder. The material in three of these easily portable containers would suffice to make a nuclear explosive. (Von Hippel 2001)

Figure 29: Plutonium Containers



International Status and Developments

France

In France, like the US and Great Britain, plutonium separation began as a part of the nuclear weapons research program developed after World War II. Three plutonium producing reactors were put into operation between 1956 and 1958 at Marcoule. UP11, the first full-scale reprocessing plant to separate and refine plutonium, was completed there in 1958. (Schneider 1997)

Cogéma was established in 1976 to own and operate the facilities developed for the weapons program. (Schneider 1997) Cogéma operates two large scale reprocessing plants at La Hague, UP2 and UP3, each with a capacity of approximately 800 MTHM per year. Together, the two plants at La Hague account for roughly half of the spent fuel reprocessing in the world. UP2 was started up in 1966, originally to reprocess Magnox fuel from the older gas cooled reactors. Its "nominal" capacity varied and was finally put at 400 tons per year. In 1976 it was modified to enable the reprocessing of oxide fuels of the more common light water reactors (LWRs). The plant was further modified and expanded in 1994, up to its current nominal capacity of 800 MTHM per year. UP3 came on line in 1990. (Schneider 1997)

The La Hague’s development has depended on important contracts from foreign clients: more than half of the spent LWR fuel processed at La Hague has been of foreign origin. UP3 was in fact, financed entirely by foreign clients, and spent its first ten years reprocessing only foreign fuel. (Schneider 1997)

Electricité de France (EdF), the national power utility in France, has made provision to store reprocessed uranium (RepU) for up to 250 years as a strategic reserve. Currently, reprocessing of 1,150 tonnes of EdF used fuel per year produces 8.5 tonnes of plutonium, which is immediately recycled into MOX – fuel, and 815 tonnes of reprocessed uranium. Of this about 650 tonnes is converted into stable oxide form for storage. Although EdF has demonstrated the use of reprocessed uranium in its commercial nuclear power plant reactors, it is currently uneconomic due to conversion costing three times as much as that for fresh uranium. (World Nuclear 2005)

United Kingdom

Britain is the second largest reprocessor of civilian spent fuel in the world, behind France. British reprocessing occurs at the Windscale (later renamed Sellafield) plant in the north-west of England. Initially, the plant was used for recovery of plutonium for weapons, which was fed by weapons-production reactors also on the site. From 1969 to 1973 civilian spent fuels were also reprocessed, using part of the plant modified for the purpose. A large scale oxide fuel reprocessing began with the commissioning in 1994 of the Thermal Oxide Reprocessing Plant (THORP) (approximately 700 MTHM per year). About 70 percent of the first ten years' production at THORP was dedicated to imported foreign fuel, as the income from the import contracts financed much of THORP. (Berkhou 1997)

In its first 12 years of operation THORP has generally fallen short of its production targets. It has reprocessed 5,644 MTHM of fuel, missing its first ten-year target, of 7,000 MTHM. In 2004 it reprocessed 590 MTHM, again missing a target of 725 MTHM. (London Times 2005)

Japan[44]

Similar to the US, at the beginning of its nuclear program in the late 1950's, Japan planned for reprocessing to "close the fuel cycle" (i.e., recover the plutonium and usable uranium from spent fuel). Since the final disposal method cannot be specified until Japan adopts a formal HLW disposition policy, which it has not, reprocessing is still the only official option for dealing with spent fuel under this licensing law, which allows spent fuel to be stored only at reactor sites (in specified amounts) and at specified reprocessing companies' sites.

The Tokai Reprocessing Plant (TRP), the first reprocessing plant in Japan, started operating in September 1977. With a capacity of 100 MTHM per year, it is modest in size compared to both the rate at which spent fuel is created in Japanese reactors, approximately 1,000 MTHM per year, as well as the two major European facilities (La Hague and Sellafield). Thus, in order to meet its reprocessing policy position, Japan has been exporting its spent fuel to Europe for reprocessing, but must accept back the reprocessed plutonium, uranium and HLW.

In order to comply with its closed fuel cycle policy, Japan Nuclear Fuel Limited was created in 1980 by the Japanese utilities to raise capital for, and construct, a 800 MTHM per year facility. This facility, located at Rokkasho, was to come on line in the early 1990s followed by a second facility around 2010. However falling demand for plutonium in the 1980s, along with the existing contracts with the European reprocessors delayed construction. At the same time, the promise of fast breeder reactors, which spawned the closed fuel cycle policy, had faded, causing a shift to MOX fuel from the reprocessors.

The reprocessed materials returning from Europe, plutonium in particular, generated unease and criticism by Japan's neighbors on safety and non-proliferation grounds: even using the plutonium in MOX fuel, there was still an increasing stockpile of plutonium. This led to 1991 to a "no plutonium surplus policy," under which Japan committed not to accumulate excess plutonium by creating MOX and utilizing European storage.

The Rokkasho reprocessing facility began initial startup procedures in July 2005, and is currently scheduled to come on line in 2006 or 2007. The current sunk investment Rokkasho is reported to be $2.4 trillion yen (~$20 billion). (Takagi 1997) Even with the Rokkasho's projected 800 MTHM reprocessing capacity, Japan will still have a net surplus of spent fuel, which it will have to either send to Europe for reprocessing (although it is not clear if La Hague or Sellafield will accept it), or develop greater spent fuel storage capacity domestically.

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[44] Unless otherwise noted, data from this section is from (Harvard 2001)

CHAPTER 5: TRANSPORTATION OF RADIOACTIVE MATERIAL

Radioactive material, such as radioactive medical isotopes, research and test reactor materials, and low level waste, has been transported around the U.S. for well over 60 years. Spent fuel from commercial nuclear power plants has been transported since the mid-1960s. However, the magnitude of these shipments will increase substantially when the spent fuel is moved to a permanent repository such as that proposed at Yucca Mountain. Moving spent fuel introduces numerous challenges not encountered with the storage of spent fuel:

> During transportation, there are inevitably somewhat greater complexities, costs and risks than there are when the fuel is simply sitting in a storage facility—and in recent years, transportation of spent fuel and other nuclear material…has been the subject of substantial political controversies. (Harvard 2001)

Transportation of spent nuclear fuel is controversial, belying an excellent safety record.

> The safety record for spent fuel shipments in the U.S. and in other industrialized nations is enviable. Of the thousands of shipments completed over the last 30 years, none has resulted in an identifiable injury through release of radioactive materials. (Harvard 2001)

Spent fuel will have to be shipped overland by rail or truck through nearly every state, hundreds of local communities, and the lands of numerous sovereign Native American tribes. Each of these jurisdictions will have to be involved in the preparation for these shipments and with emergency planning in the event of an accident. In the western states, the Western Governors' Association (WGA) and the Western Interstate Energy Board (WIEB) have been involved in a collaborative transport safety planning effort with responsible federal agencies. The Energy Commission coordinates a California interagency taskforce and has participated in the Western Governors' Association and WIEB nuclear waste transport planning efforts. Numerous federal and state agencies have different roles and responsibilities for ensuring the safe transport of nuclear materials. Consultation among the appropriate federal, state and local governments in preparing for shipments can take years.

This chapter first reviews the regulatory structure in the U.S. for transporting nuclear materials. The chapter then provides a brief overview of the safety, security and costs of transporting nuclear materials. Finally, potential transportation routes for spent nuclear fuel and the implications of such routes for California are discussed.

Regulatory Overview for Transportation of Spent Fuel

The federal government and the states work together in what is at times an uneasy alliance to oversee the safety of nuclear waste transport. The sometimes conflicting or overlapping roles of state and federal agencies, combined with the uncertainty over the ultimate, long-term destination for nuclear waste materials, can lead to delays or inconsistencies in the regulation of nuclear waste transport.

Numerous federal agencies share some portion of the jurisdiction and responsibility for ensuring the safe transport of nuclear materials. Key federal agencies involved in the regulation of transportation of radioactive material include the following:

- The **Department of Transportation** (DOT) enforces the Federal Hazardous Materials Regulations which require that "hazardous materials are safely contained in their packages and that their hazards are effectively communicated to the carrier and any emergency responders." (49 CFR, Parts 100-199) These regulations define shipper responsibilities, materials classification, packaging regulations, incident reports, route selection, carrier responsibilities and container manufacturer responsibilities. Radioactive materials are a subset of the broader category of hazardous waste regulated by DOT.

- The **Nuclear Regulatory Commission** (NRC) regulates the packaging, preparation and transfer of commercial nuclear material. (10 CFR, Part 71) It issues certificates for radioactive materials packaging that verify compliance with safety standards and takes the lead role in investigating accidents involving NRC-certified packages. NRC requirements include: advance approval of proposed shipping routes, armed escorts through high population centers, visual surveillance of cargo during stops, and calls to communications centers at least every two hours.

- The **Department Of Energy** (DOE) is responsible for construction, management and operation of the proposed Yucca Mountain repository. DOE will be required to fund emergency response training for spent fuel shipments to Yucca Mountain.

- The **Environmental Protection Agency** (EPA) maintains an oversight role for the Waste Isolation Pilot Plant (WIPP) that includes audits and inspections at the waste generator site to determine if DOE is properly tracking waste.

- The **Federal Emergency Management Agency** supervises the implementation of emergency response plans during hazardous materials releases.

In California many state agencies also share roles and responsibilities in nuclear waste transport (California Agencies 2005). Key agencies include the following:

- The **California Energy Commission** (Energy Commission) coordinates the California Nuclear Transport Working Group, a working group on the Yucca Mt. High-Level Waste Repository and is the Governor's designee to the Western Governors' Association WIPP Transport Technical Advisory Group and the WIEB High Level

Waste Committee, both of which are regional groups working together and with federal agencies to prepare for federal shipments of nuclear material.

- **California Department of Health Services** (CDHS) manages licensing, inspection and enforcement related to radioactive materials use and transport. CDHS also oversees mitigation efforts in the event of an accident.

- **California Department of Transportation** (CDOT) helps mitigate highway accidents, handles clean-up of hazardous materials spills and coordinates the transportation permit program for oversize/overweight trucks.

- **California Environmental Protection Agency** (CEPA) is responsible for coordinating the Railroad Accident Prevention and Immediate Deployment (RAPID) Force which provides assistance following railroad or highway hazardous material incidents.

- **California Highway Patrol** (CHP) designates routes for highway radioactive material shipments and is the Governor's designee for advance notice of specified radioactive materials shipments. CHP also enforces truck and driver safety regulations.

- **California Public Utilities Commission** (CPUC) is federally certified to cooperate with the Federal Railroad Administration in conducting detailed inspections of identified rail routes including track, equipment, signal and train control, railroad operating practices, and compliance with state and federal hazardous materials and other applicable.

State versus Federal Responsibilities

States participate in the enforcement of federal regulations and can also promulgate their own regulations, as long as these regulations are not substantially different from federal regulations and do not unreasonably burden commerce. States may also pass laws that address issues or areas not covered under federal regulations. States retain the authority to determine driver qualifications, ensure safe operation of motor vehicles and conduct inspection and enforcement activities. (Smith 2004) Numerous state and local laws have been challenged in court on the grounds that they are preempted by federal laws or that they violate the Commerce Clause of the U.S. Constitution. Courts have generally validated laws that are not unduly burdensome and do not directly encroach on federal regulations, such as headlight illumination requirements and fee assessments to cover state costs. The Supreme Court re-affirmed that the NRC has exclusive jurisdiction to regulate radiation hazards. Table 17 outlines state and local regulations that have been ruled on by federal courts. (Smith 2004)

Table 17: State and Local Regulations Ruled on by Federal Courts

Invalid Rules • Absolute shipping bans • Additional placarding requirements • Statewide curfews • Burdensome permitting requirements • Registration requirements for rail shipments • State penalties for violation of federal transportation regulations • Fees associated with invalid permits • State prenotification that differs from federal requirements
Valid Rules • Headlight illumination • Additional placarding requirements (conflicting cases) • Immediate accident reporting • Circuitous routing through urban areas, with rush hour curfews • Transport vehicles equipped with two-way radios to assist accident reporting • Fees to cover costs related to hazardous materials transportation • Permits for unloading, transferring or storing hazardous materials on railroad property • Driver training requirements, such as mountain driving experience • Vehicle inspection at loading and unloading points

Source: (Smith 2004)

One explicit right that states exercise in the area of hazardous waste transport is the authority to establish and enforce a highway routing designation for hazardous transport. (29 USC 5125(c)) Shipments containing more than a specified quantity of radioactive material, categorized as highway route-controlled quantity materials, are required to follow state designated routes. (49 CFR, 171-179) In California, the CHP exercises this authority. The CHP designates when shipments may occur and over which routes they may occur. (CVC 33000) The CHP requires that it be notified of any radioactive material shipments at least three days before the shipment is made. The CHP in turn notifies the police chiefs of all cities through which a shipment is to be transported. (CVC 33002) The CHP inspects some[45] radioactive shipments originating in California and performs a safety inspection on the transporting vehicles. Finally, it also requires drivers of radioactive shipments to obtain a radioactive materials driver's certificate. (CVC 12524)

Spent Fuel Transportation Regulations

Spent fuel from nuclear reactors is a specific form of regulated radioactive waste. For transportation, spent fuel is packaged in "Type B" packages, which are strong packages design to provide greater protection in the event of an accident. Packaging is designed such that external radiation levels do not exceed regulatory limits.

[45] The CHP inspects all transuranic waste shipments originating in California.

DOT regulations on spent fuel transportation include the following:

- 49 CFR 172.403 requires a Yellow III label on all packages containing spent fuel. The Yellow III label indicates that the package requires the greatest degree of control by the carrier and the materials have the highest degree of transportation risk

- 49 CFR 173.442 requires that radiation levels are limited to less than 10 millirem per hour at any point two meters from the outer edge of the truck or rail car containing spent fuel

- 49 CFR 178 details materials, necessary safety devices and construction requirements for canisters containing spent nuclear fuel

- 49 CFR 179 provides the specifications for tank cars, and 49 CFR 180 contains maintenance, repair, and testing requirements for spent nuclear fuel and high level waste packages.

NRC regulations on spent fuel transportation include the following:

- 10 CFR Part 71 requires all casks for shipping spent nuclear fuel to meet certain performance criteria for normal transport and severe accident conditions. Cask designs undergo a series of tests, including a 9-meter drop onto an unyielding flat surface, a 1-meter drop onto a vertical steel bar, exposure of the entire package to fire for 30 minutes and immersion in 1 meter of water. Additionally, an undamaged cask must be able to survive submersion in 15 meters of water and 200 meters of water. When undergoing these tests, the cask must not release more than the regulated amounts of radioactive material in one week, nor may they emit radiation at a dose rate of greater than 1 rem per hour at a distance of one meter. Finally, the cask must prevent the enclosed material from undergoing a nuclear chain reaction as a result of the test conditions.

- Spent nuclear fuel is included in the Highway Route-Controlled Quantities of Radioactive Materials (49 CFR, 173.401) that are required to use preferred routes to reduce time in transit and reduce risk to the public. Prior to shipment, the shipper must select routes and prepare a written plan for the NRC listing the origin and destination of the shipment, scheduled route and included stops, and estimated time of departure and arrival. The NRC reviews and approves the plans. (49 CFR, 379.101) Route designations must be preceded by consultation with effected local jurisdictions to ensure consideration of all impacts of designated routes. (49 CFR, 379.103)

- 49 CFR 174-177 details requirements for transporting spent nuclear waste canisters by rail, air, vessel and highway.

Role and Policy of the Western Governors' Association

The WGA's Radioactive Waste Safe Transportation Program consists of 12 western states that have collaborated on plans and preparations for shipment of selected defense-related transuranic waste to the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico.[46] Shipments began in March 1999; roughly 3,650 shipments, or 18% of the total planned, have been successfully completed with no reported incidents. Shipments have been made from eight DOE sites, including Lawrence Livermore National Laboratory (LLNL) in California. (WGA 2004a)

Most of the transuranic waste in California is generated at LLNL. Until the spring of 1990, the LLNL waste was sent to the Nevada Test Site in southern Nevada for storage. Beginning in 1990 the transuranic waste generated at LLNL was stored onsite in preparation for shipments to WIPP that began in 2004.

In 2004 DOE planned 61 truck shipments of transuranic waste originating from the Nevada Test Site that were routed through California to the WIPP. Additionally, 20 shipments were completed in 2004 and 2005 from LLNL to WIPP. The waste planned for transport through California is "contact handled" waste. Thus, the radiation it emits is not very penetrating. This waste does not require lead or other heavy shielding to protect workers or the public. (Energy Commission 2004a) DOE, as a result of cost-benefit analysis, has identified highway transportation as the preferred shipping method for transuranic waste. Figure 30 presents a map detailing the existing trucking routes of transuranic waste to the WIPP.

Figure 30: Route Map Detailing Trucking Routes To The WIPP

Source: (WIPP 2005)

[46] Transuranic wastes include elements with an atomic number higher than that of uranium (92). Transuranic waste often includes rags, clothing and tools.

The WGA, DOE, and other California agencies prepared a Transport Safety and Emergency Response Plan for the transuranic waste shipments traveling through California. The plan includes the following items: (Energy Commission 2004a)

- **Shipment Inspections and Escorts:** The CHP inspects all shipments originating in California. The CHP escorted the first shipments in California.

- **Emergency Preparedness:** The Governor's Office of Emergency Services coordinates planning and emergency response preparation for WIPP shipments. The office has created plans for responding to an accident and helped train and equip emergency responders along shipment routes.

- **Routes and Advance Notification:** The CHP designates routes for highway radioactive material shipments and receives advance notice of material shipments.

- **Shipment Tracking:** The CHP, California Energy Commission and the Office of Emergency Services track radioactive shipments in California using a satellite-based tracking system.

- **Bad Weather and Road Conditions:** Radioactive shipments must avoid adverse weather and bad road conditions. The California DOT and CHP provide information on highway conditions and have worked with DOE to identify appropriate safe parking areas in the event of bad weather or road conditions.

- **Schedule Shipments to Avoid Peak Tourist Events:** Shipments are scheduled to avoid holidays and peak tourist events along routes.

Under WGA/DOE protocols, DOE is required to identify shipping routes a few years prior to shipment. DOE primarily uses interstate highways for WIPP shipments and consults with states regarding use of routing alternatives. Since 1999, California officials, including California Energy Commissioners, and the WGA, have objected to DOE's increasing use of predominantly California routes for shipments to and from Nevada Test Site. There is concern that this will set a routing precedent for spent fuel shipments to Yucca Mountain. California officials have noted that there are shorter, more direct routes available along higher quality roads with more timely emergency response capability. These routes are in Nevada and avoid transportation through Las Vegas and over the Hoover Dam. For example, Nevada State Route 160 is 108 miles shorter than the California route and has long stretches of four-lane roadway unlike two-lane California State Route 127. The WGA has negotiated an agreement with DOE whereby the first approximately half of the NTS shipments to WIPP use predominantly California routes, while the remaining shipments will exclude predominantly California routes. (WGA 2004b)

The WGA relied on the experience gained from the WIPP transportation program when they created their 2005 *Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste* Policy Resolution. The WGA Policy supports a permanent, national repository for spent nuclear fuel and encourages DOE to work with states to implement a policy for safe storage and transportation of spent nuclear fuel and high level waste. More specifically, the WGA suggests that DOE and other federal agencies commit to the following:

- Determine shipping origins and destination points as early as possible,

- Ensure the availability of rail and truck shipping casks,

- Conduct full-scale testing of casks to be used to transport spent nuclear fuel and high level waste,

- Prepare a comprehensive transportation plan that includes analysis of all needed transportation-safety activities in a single document,

- Develop responsible criteria for selected shipping routes,

- Develop a sound methodology for evaluating optional mixes of routes and transportation modes, and

- Conduct a thorough review of the risks of terrorism and sabotage against spent fuel and high level waste shipments and work with the state governments to assure that adequate safeguards are in place prior to shipments occurring

The WGA believes that DOE or any operator of a central interim storage facility must look to the WIPP transportation and cesium capsule return programs for guidance. WGA’s specific recommendations are as follows:

- A safety and public information program similar to that developed with the western states for shipments of transuranic waste to WIPP and cesium capsules to Hanford should be utilized for all highway route-controlled quantity DOE shipping campaigns. Safety programs should be evaluated and improved as needed.

- The WIPP Transportation Safety Program Implementation Guide provides an appropriate framework for transportation planning, and a similar document should be used as a base document for DOE’s or any other central interim storage facility operator’s various transportation programs.

- DOE or any other central interim storage facility operator should follow the WIPP example of working through its regional cooperative-agreement groups to propose a set of shipping routes to affected states and tribes for their review and comment. This process should result in the identification of a set of primary and secondary routes from each site of origin to each destination. DOE should require the use of these routes through mandatory contract provisions with any private contractors.

- DOE should work to identify flexible funding resources and cooperative agreements between their civilian, power and defense agencies as a means for supporting WGA and DOE application of lessons learned through the WIPP safety program to other DOE shipping campaigns. (WGA 2005)

Safety, Security and Economics of Transportation

Significant amounts of radioactive material are transported by rail or truck in the U.S. each year. The types of materials include radioactive isotopes such as those used in medical applications (e.g., cesium 137 and cobalt-60), research and test reactor materials (e.g., transuranic waste), and "low level" waste.[47] Shipments of spent fuel have occurred in lesser quantities:

- On a national level, approximately 2,700 shipments of spent nuclear fuel have occurred over the past four decades. (DOE)

- DOE has transported about 2,500 MTHM of DOE-managed spent nuclear fuel to three facilities: the Hanford Site, Idaho National Laboratory, and the Savannah River Site, where it will be stored until the national repository becomes available. (DOE 2001b)

- In California, spent fuel rods from PG&E's Humboldt Bay nuclear facility were shipped to General Electric's Vallecitos Nuclear Center in Pleasanton, California in the 1960s and 1970s. Vallecitos is licensed by the NRC to receive used nuclear fuel for research, development and testing. According to PG&E, 66 fuel rods were shipped in 11 shipments over the time period. Just over 300 fuel rods remain in the Humboldt Bay spent nuclear fuel pool. (PG&E 2004d)

The overall volume and number of spent nuclear fuel is expected to increase substantially when spent fuel is transported to a permanent repository such as that proposed at Yucca Mountain or to centralized interim storage facilities.

Transportation Safety

The U.S. nuclear industry has a mostly clean record of transportation-related incidents. Between 1979 and 1995 roughly 1,300 shipments (1,045 by highway and 261 by rail) of commercial spent nuclear fuel resulted in only 8 reported accidents. None of these eight accidents resulted in damaged fuel casks, compromised shielding, or the release of radioactive material. (NRC 2000) On a global level, by 1995 over 88,000 tons of spent nuclear fuel had been shipped by sea, road and rail with an "excellent safety record." When compared to fuel shipments for fossil energy, spent nuclear fuel transportation has caused far fewer fatalities and large-scale environmental damage. (Harvard 2001, p.20) A joint study by Harvard University and the University of Tokyo concluded that, "With careful attention to safety, including extensive pre-planning and effective and

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[47] Low level waste is any nuclear waste that is not spent fuel, high level waste, or transuranic waste. It consists of products from research, medical and industrial processes that include small amounts of short lived radioactive materials dispersed through large quantities of other material.

independent regulation, transportation of spent nuclear fuel can be accomplished with very little risk to the public.” (Harvard 2001, p.19)

Breaches of safety have occurred. Stringent regulations are only useful if there is strict compliance. In April 1988 casks used for transporting spent fuel among Germany, Switzerland, France and the United Kingdom were found to have levels of radioactive contamination on the outside surface of the casks. Although the contamination levels were low, the levels far exceeded legal limits. The German Environmental Minister discovered that the industry knew about the excessive levels of radiation earlier but had not informed the government. A decade later in 1998 similar contamination was discovered on casks used in the early 1990s to ship spent fuel from Japan to Europe. The Japanese firm that had manufactured the casks later acknowledged that the data on radiation protection provided by a particular set of casks had been falsified. (Harvard 2001, pp.20-21) Since the 1998 incident, “issues concerning data on transport cask safety have continued to arise.” (Harvard 2001)

Nevada’s Concerns

As the state where a permanent spent fuel repository may be located, Nevada has particular concerns with regard to safety and transporting spent nuclear fuel. Specifically, Nevada is concerned that to date none of the NRC-approved shipping casks have been subject to full-scale testing. The NRC instead relies on scale model testing and computer analysis to assess cask performance. (Halstead 2005b) Additionally, in the final EIS for Yucca Mountain DOE’s accident and sabotage analysis assumed that shipping casks would be loaded with 14-15 year old spent nuclear fuel. Nevada believes that repository shipments could include 5-10 year old fuel, resulting in greater radiological hazards than those evaluated by DOE. (Halstead 2005b) Another major concern is with potential shipments through Las Vegas to Yucca Mountain and impacts on safety and tourism.

The Nevada Attorney General filed a petition in June 1999 requesting a general strengthening of the current transportation safeguard regulations and a comprehensive reexamination of the consequences of radiological sabotage. Nevada cited concerns about terrorist threats to repository shipments and documented the vulnerability of shipping casks to high-energy explosives. The NRC accepted public comments on Nevada’s petition through February 2000, but has yet to officially respond to the petition.

Another concern of Nevada is DOE’s selection of the Caliente Corridor as the preferred transportation route (see below for more discussion on the Caliente Corridor). Nevada is concerned that DOE did not perform sufficient analysis when choosing a preferred corridor from the five outlined in the final Yucca Mountain EIS. DOE speculated that the differences in environmental impacts among the rail corridors would be small and thus did not consider environmental impacts as a major factor in their selection process. DOE concluded that flood plain impacts “probably would occur”, but has yet to study these impacts in depth. Nevada expressed environmental-related safety concerns in their petition including flood-caused derailments. (Nevada v. DOE 2005)

Transportation Security

Spent fuel shipments must be protected against potential theft and sabotage intended to spread radioactive contamination. The NRC has regulations to provide such protection, and some studies have claimed that even an attack with shape-charged explosives on the casks would spread only a minor amount of radioactivity. (Harvard 2001, p.21) Nevada has argued that spent nuclear fuel and high-level waste shipments to a centralized national facility will likely be viewed by terrorists as a highly desirable target. Nevada has also long advocated cask standards for terrorist-related attacks which the NRC has not yet created. (Halstead 2005b) A recent DOE sponsored study of cask sabotage by Sandia National Laboratories concluded that both truck and rail casks could be breached by a single stage attack and that the radioactive material released would be six to ten times greater than previous estimates. (Sandia 1999) The State of Nevada has expressed concern that the Sandia terrorist attack study, as well as others relied on by DOE, underestimate the consequences of a terrorist attack in the post-September 11, 2001 world. The pre-2001 studies are based on what may be outdated assumptions and less-than-realistic attack scenarios in the post-September 11, 2001 world of terrorism. (Halstead 2005b) NATO recently completed a study that assesses updated attack scenarios on spent nuclear waste casks; however it is not yet publicly available.

To demonstrate their security concerns, a group of Greenpeace members successfully boarded one shipment of nuclear waste while it navigated the Panama Canal on the way to Japan from France in the winter of 1998. The ship's route had been kept secret prior to departure due to political opposition, although the Greenpeace arrival caused the ship's operator to re-evaluate their security plans. (Environment 1999)

Transportation Costs

The costs of transporting spent nuclear fuel are a function of the distances involved, the quantities of material, the levels of security involved, and the mode of transportation, among other considerations. DOE estimated the total costs of transporting civilian spent nuclear fuel to the Yucca Mountain repository to be $4.76 billion for some 86,300 tonnes of spent fuel, which is about $55 per kilogram of heavy metal. This estimate is similar to the estimate of the Nuclear Energy Agency of the Organization for Economic Cooperation and Development for the costs of transporting nuclear fuel in Europe. The Harvard/ University of Tokyo study notes that "In Germany, … 30,000 riot police were required to protect the first shipment of nuclear waste to the Gorleben site, at a cost of some $57 million, for a modest amount of spent fuel." (Harvard 2001, p.22)

Potential Transportation Routes

Currently, 72 commercial and 5 DOE sites across the country are waiting to transport nuclear waste to a permanent repository. Commercial spent fuel would comprise about 63,000 MTHM (90%) of the first 70,000 MTHM shipped to the repository, and 105,000 MTHM (88%) of the total projected repository inventory. (Halstead 2003)

Route Selection

California, like many states, has designated highway routes for “highway route controlled quantities” (HRCQ) of radioactive material, as allowed under 49 CFR 397.101. A state’s routing designation must follow an analysis that takes into account the following factors:

- A determination of routes that minimize impacts
- Identification of alternate highway routes available
- Development of a list of route comparison factors such as population density along the route, frequency of rest and refueling locations, and expected response time of law enforcement or emergency agencies
- Selection of a route that best minimizes impacts based on an evaluation of route comparison features
- Documentation of the entire routing analysis that serves as a basis for routing

Computer models maintained by DOE’s Oak Ridge National Laboratory and Sandia National Laboratory can be used to assist in routing determinations as well.

No routing regulations exist for railroads, in part because rail rights-of-way are privately owned and thus states have limited regulatory authority. (Smith 2004) 49 CFR Part 174 regulates carriage by rail, but only routing for explosive materials. The shipper and rail carrier normally plan the route jointly, considering factors such as starting and ending points, the shortest distance or time in transit, the amount of traffic, and track and bridge conditions relative to the weight of the shipment load. The shipper is required to send the rail route plan to the NRC who examines the route for operational safety and safeguards. It has been suggested that DOT create rail routing guidelines similar to the highway regulations to reduce rail shipments of radioactive materials through highly populated areas. (TECWG 2005) DOT has not produced such guidelines, and the railroad industry is strongly opposed to new routing regulations. Few realistic alternatives exist to routing through major urban areas because the highest quality tracks and signal systems serve the high-density traffic between major cities, and because interchange points are located in major cities. (TECWG 2005)

Table 18 below compares the characteristics of highway and rail routing decisions.

Table 18: Characteristics of Highway and Rail Routing

Highway	Rail
Requirement that carriers follow "Preferred routes" for HRQC of radioactive material	No required rail network is identified
State routing agency identified as responsible for alternative route decisions	No rail routing authority identified
Reduce time in transit required	No requirement for time in transit (DTS policy will result in reduced transit time)
Explicit deviations from preferred routes are provided in regulations	No explicit deviations have been identified
Interstate highway system provides a large array of potential alternative routes	The rail network is comparatively smaller and does not have as many suitable potential alternative routes
Business decisions for specific transportation operations do not typically play a significant role in highway routing	Business decisions for overall operations play an important role in rail routing because infrastructure is privately owned and maintained.

Source: (WIEB 2003)

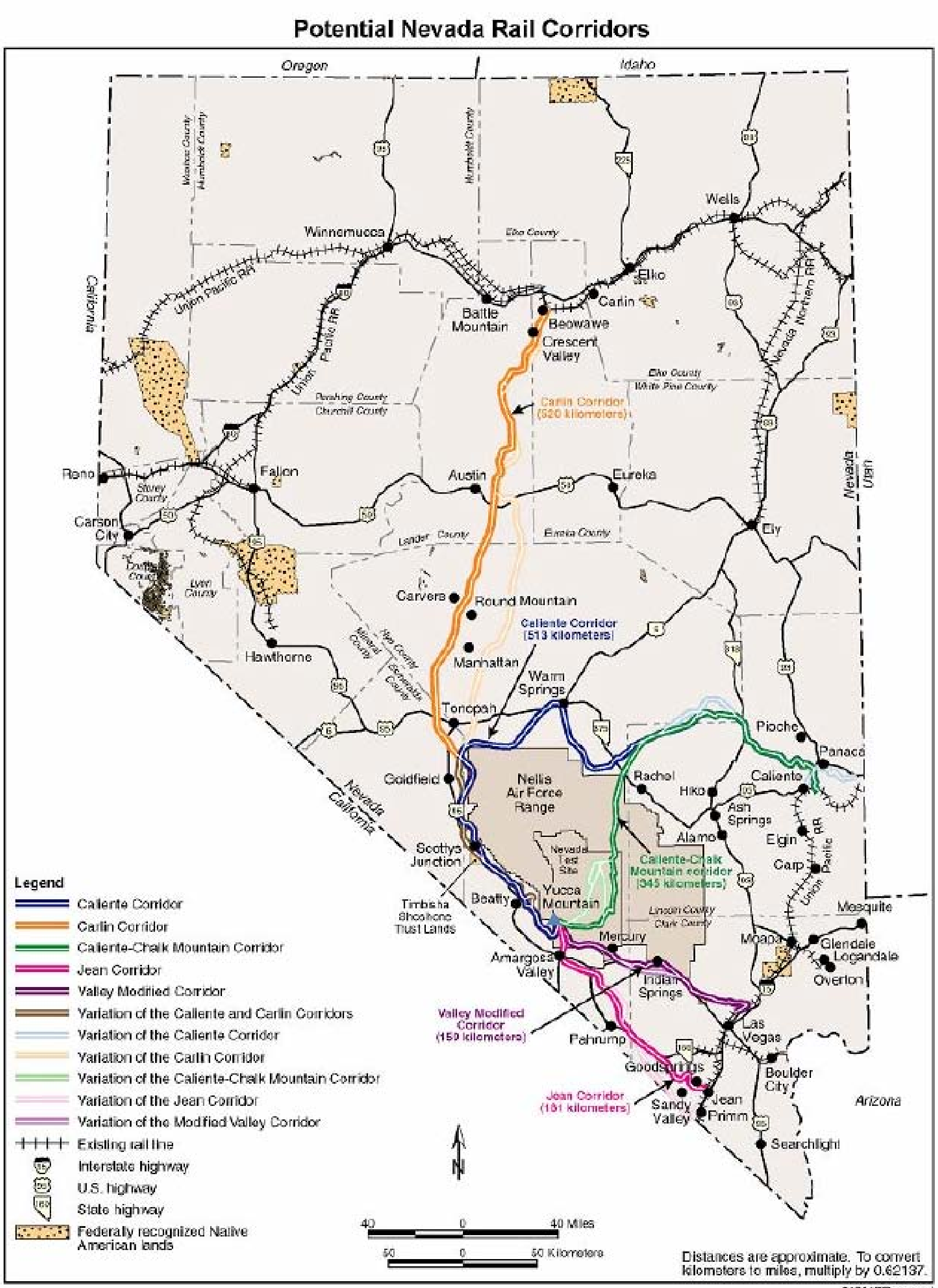
Proposed Yucca Mountain Transportation Routes

DOE has identified two likely transportation schemes associated with the Yucca Mountain repository, one relying primarily on transportation via trucks, the other a mostly rail case. Rail casks have a larger capacity than truck casks and thus require fewer total shipments. For this reason, DOE currently favors the rail transport option to Yucca Mountain. (Halstead 2005a) However, there is currently no rail access to Yucca Mountain. DOE announced in December 2003 a preference for a 320-mile spur along the Caliente Corridor to connect an existing mainline railroad near Caliente, Nevada to Yucca Mountain. This new rail project, expected to cost over $1 billion dollars, was chosen from five corridors outlined in DOE Final Environmental Impact Statement. (DOE 2003)

Figure 31 shows the Caliente Corridor along with the four other options considered. The Caliente Corridor runs west from Caliente Junction to Warm Springs and then turns south through Scotty's Junction before arrival at Yucca Mountain. The Carlin Corridor was chosen as the backup option.

DOE has proposed two inventory disposal scenarios: one lasting 24 years and the other lasting 38 years. (DOE 2002c) Under the former scenario, DOE would transport 70,000 MTHM of spent nuclear fuel and high-level radioactive waste to Yucca Mountain over a 24-year period. The remaining 49,000 MTHM would be sent to an unnamed repository. If there is no secondary repository, in a second scenario DOE would send all 119,000 MTHM of spent fuel to Yucca Mountain over a 38-year period.

Figure 31: Potential Nevada Rail Corridors



Source: (DOE 2002c)

Table 19 compares the quantity and number of shipments of commercial spent nuclear fuel shipped in the United States between 1964 and 2001 with the proposed Yucca Mountain transportation plan.

Table 19: Transportation of Commercial Spent Fuel Quantity

	Estimated Quantity Shipped (MTHM)		Estimated Number of Shipments		
				Proposed Shipments to Yucca Mountain[48]	
	Past Quantity Shipped: 1964-2001	Proposed Quantity Shipped to Yucca Mountain	Estimated Shipments: 1964-2001	Mostly Rail Scenario	Mostly Truck Scenario
Truck	876		2,369	1,079-3,122	52,786-105,685
Rail	1,581		326	9,646-18,423	300
Total	2,457	63,000-105,000[49]	2,722	10,725-21,545	53,086-105,985

Source: (Halstead 2003; DOE 2002c)

The proposed Yucca Mountain transportation plan represents a 3,877% - 4,186% increase in the quantity of commercial spent nuclear fuel transported annually in the United States. Under DOE's preferred Mostly Rail Scenario, annual rail shipments of commercial spent nuclear fuel will increase between 507% and 792% in the United States, or from 6 shipments per month to 37-48 shipments per month. If the proposed Yucca Mountain transportation plan goes into place, the number of shipments of spent nuclear fuel will increase, as well as the amount of fuel in each individual shipment.

Table 20: Projected Number of Shipments to Yucca Mountain

	(Mostly Truck) Truck Shipments	(Mostly Truck) Rail Shipments	(Mostly Rail) Truck Shipments	(Mostly Rail) Rail Shipments
Scenario 1 (2010 – 2034)	52,786	300	1,079	9,646
Scenario 2 (2010 – 2048)	105,685	300	3,122	18,423

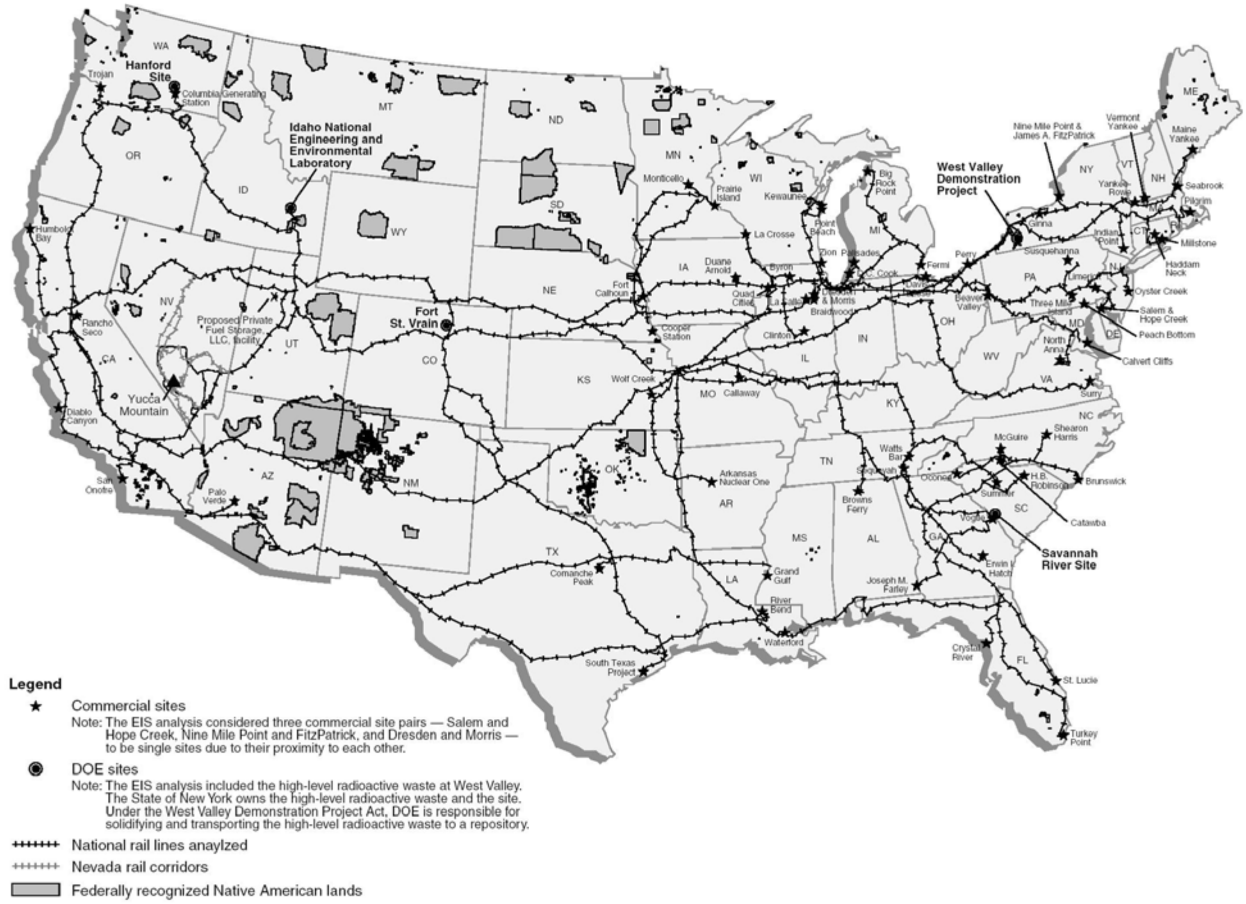
Source: (DOE 2002c)

Figures 32 and 33 show the most likely shipment routes for waste fuel and high-level radioactive waste transported to the proposed Yucca Mountain repository from sites across the country. For safety reasons, the southern routes would be used in the winter.

[48] The lower end of the range represents Scenario 1 (2010-2034) where a second repository receives some of the nation's nuclear waste. The upper end of the range represents Scenario 2 (2010-2048) where there is no second repository and the storage capacity is increased beyond the 70,000 MTHM legislative cap.

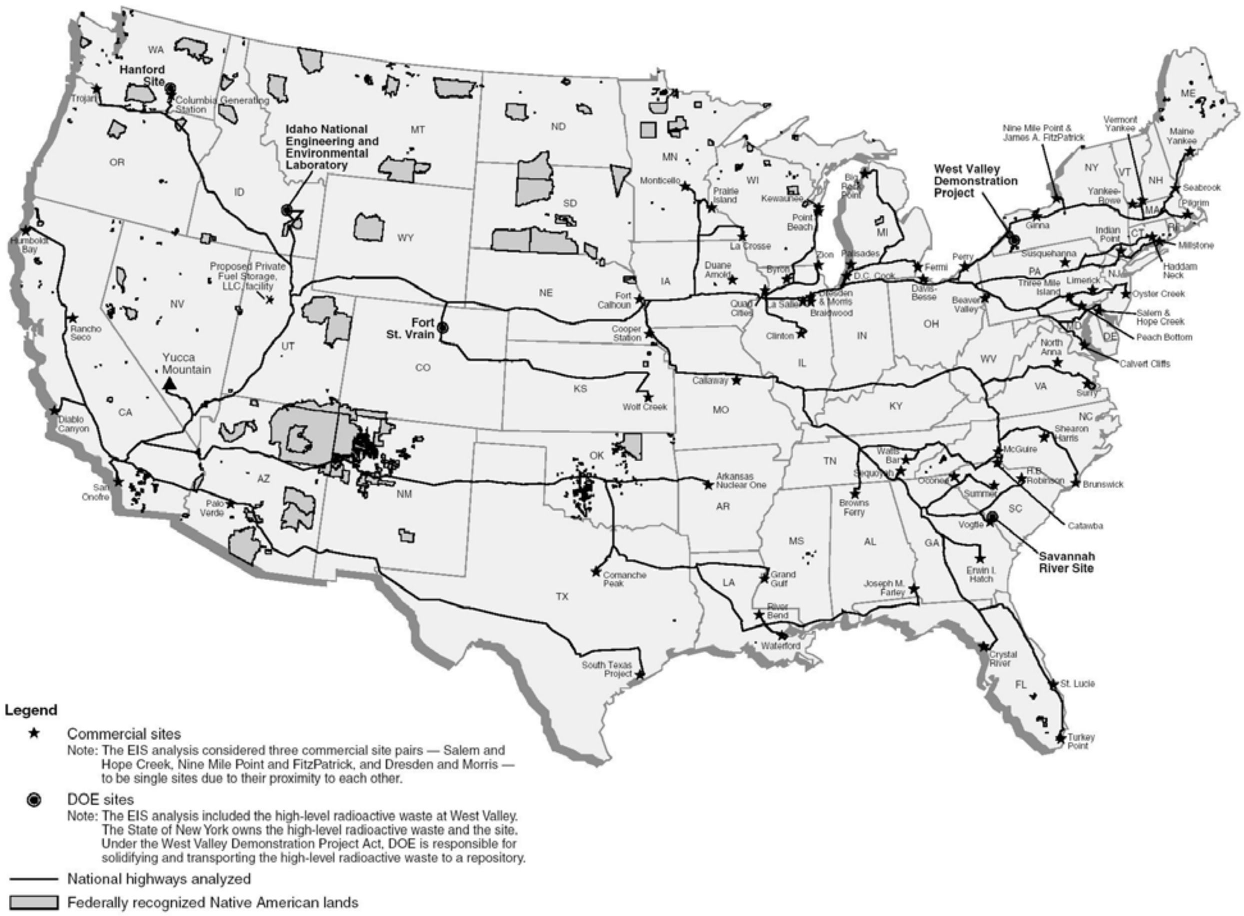
[49] The lower end of the range represents Scenario 1 (2010-2034) where a second repository receives some of the nation's nuclear waste. The upper end of the range represents Scenario 2 (2010-2048) where there is no second repository and the storage capacity is increased beyond the 70,000 MTHM legislative cap.

Figure 32: U.S. Spent Fuel Rail Shipment Routes



Source: (DOE 2002c)

Figure 33: U.S. Spent Fuel Highway Shipment Routes



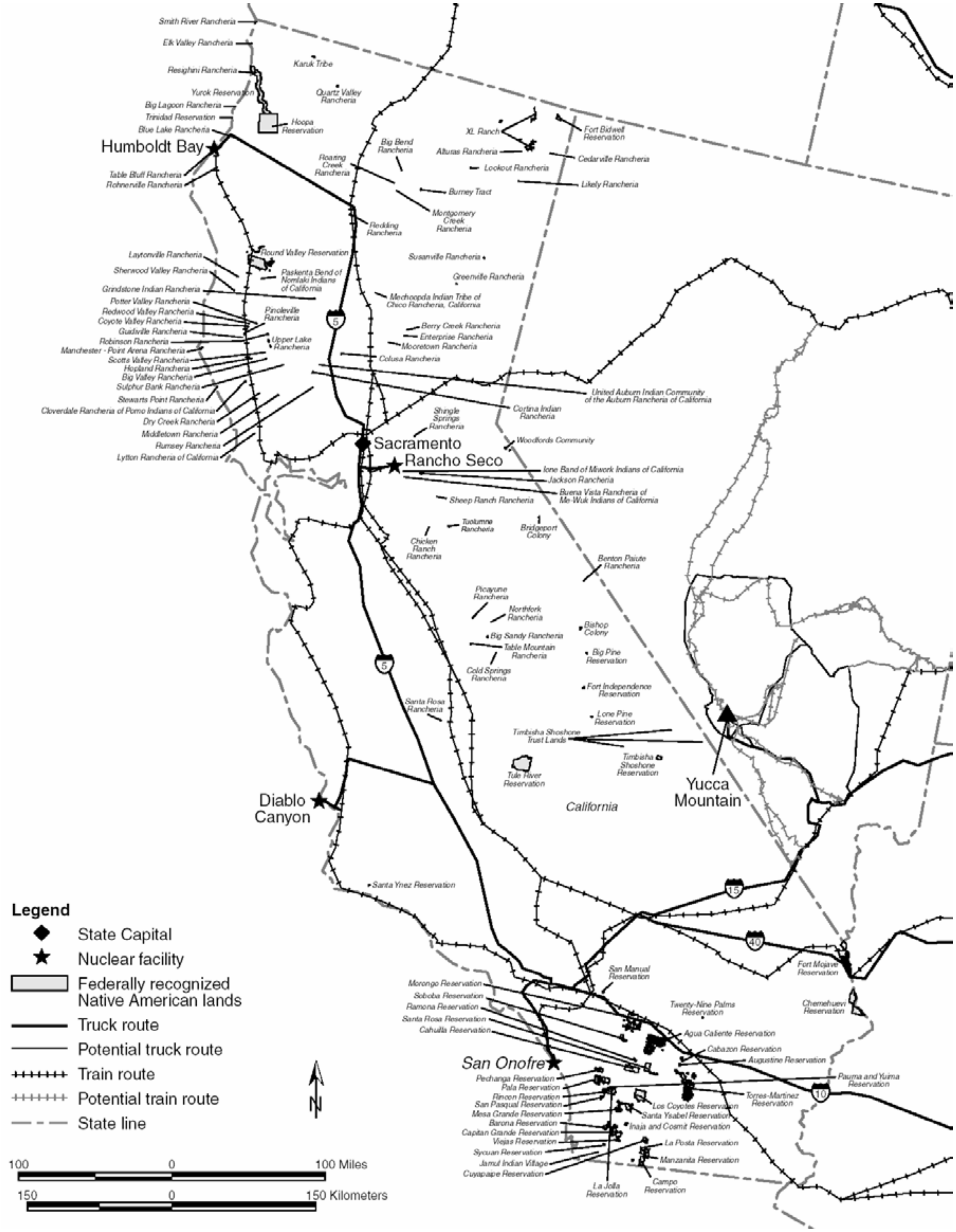
Source: (DOE 2002c)

Routes from California

Spent fuel originating in California could take one of many routes to Yucca Mountain. Figure 34 shows alternate rail and truck routes from California's nuclear power plants to Yucca Mountain.

Due to the rail and truck routes chosen, at least a portion of shipments of spent nuclear fuel and high-level waste from other states likely will be routed through California on the way to Yucca Mountain. Table 21 presents the estimated number of shipments originating in California compared to the number of shipments traveling through California.

Figure 34: Proposed Highway and Rail Shipping Routes in California



Source: (DOE 2002c)

Table 21: Potential Impacts of Yucca Mountain Transportation on California

Scenario	Shipments Originating in California	Total Shipments Through California
Mostly Truck	1,750	6,867
Mostly Rail[50]	286	660

Source: (DOE 2002c)

On July 18, 2005, DOE announced that it will use dedicated train service "for its usual rail transport of spent nuclear fuel (SNF) and high-level radioactive waste (HLW)" to Yucca Mountain. This policy decision is consistent with the position of the Western Governor's Association. (DOE 2005d)

Potential Impact of a Centralized Interim Storage Facility

Other storage options under consideration could impact transportation requirements for California spent fuel sources. A private company is investigating an interim fuel storage facility to be located in Utah (see Section 4.6 above). While transportation routes have not yet been specified for the PFS facility, PFS prefers to ship by rail. Though packaging for transport to PFS could differ from transport to Yucca Mountain, transporters would be required to meet the same federal and state requirements. Eventually, any spent fuel that has been stored at a centralized interim storage facility would have to be transported to a permanent repository. With centralized interim storage the number of spent fuel shipments would effectively be doubled. There is not yet a publicly available plan for transporting waste from PFS to Yucca Mountain. Depending on which proposed route is approved, waste from PFS may travel through California on the way to Yucca Mountain. Additionally, DOE currently requires that high-level radioactive waste transported to Yucca Mountain must come directly from the reactor site and must be transported in approved canisters. (Tribune 2004) The canisters PFS has selected are not approved by DOE and do not meet DOE's inspection requirements if they are welded shut, as PFS plans.

Fee Structure Implications For California

Individual states may assess fees for radioactive material shipments traveling through their state boundaries. Usually these fees are associated with a permit or registration requirement. These fees are collected to help the state cover the costs of shipments, inspections, escorts, emergency preparedness and response. In theory, all the costs of transporting radioactive material should be borne by the beneficiaries of the power. California currently charges a $100 annual fee per company along with a $75 renewal fee. Nevada charges a $500 annual fee per company plus $150 per truck as well as the actual cost of investigation. Arizona does not have a radioactive materials state permit fee. (Smith 2004) Table 22 compares state fees for nuclear waste transport in a selection of western states. California's fees are relatively modest in comparison to those charged

[50] The Mostly Rail scenario includes rail shipments ending at Caliente Junction, DOE's preferred ending rail node.

by other states. This may cause transportation companies to route shipments of radioactive material through California to avoid higher fees in other states.

Table 22: State Fees for Nuclear Waste Transport

State	Transportation Fee
California	\$100 annual fee per carrier \$75 annual renewal fee
Colorado	\$500 annual permit fee \$200 additional per trip
Idaho	\$5 endorsement fee per truck
Illinois	\$2,500 for the first truck cask plus \$25/mile for each mile over 250 miles in Illinois \$4,500 for the first rail cask \$3,000 for each additional rail cask
Indiana	\$1,000 per cask
Iowa	\$1,750 per highway cask plus \$15/mile for each mile over 250 miles in Iowa \$1,250 for the first rail cask plus \$100 for each additional rail cask
Nevada	\$500 permit fee \$150 additional per truck plus Actual cost for additional assessment
New Mexico	\$250 annual fee or \$75 per shipment fee
Oregon	\$500 annual permit fee or \$70 per shipment, whichever is less
Pennsylvania	\$1,000 per shipment Pennsylvania State Police assess escort fees
Tennessee	\$1,000 per cask for truck shipments \$2,000 per cask for rail shipments
Wyoming	\$200 permit fee per package

Source: (UER 2003)

CHAPTER 6: POTENTIAL FOR EXPANSION OF NUCLEAR POWER

The long-term future for nuclear power in the U.S. will be shaped in large part by trends and events beyond the energy industry. Policy priorities at both the federal and state level will be driven by national security concerns, global environmental impacts, relative costs, and success or failure in closing the nuclear fuel cycle by resolving the problem of spent fuel disposal. The specter of terrorist strikes at nuclear power plants, renewed concern over nuclear weapons proliferation, and the growing evidence of global climate change are obvious issues informing today's reinvigorated nuclear policy debate.

This chapter first focuses upon a number of factors that are resulting in a second look at the use of nuclear power for electricity generation. The chapter concludes with a summary of the energy policy recommendations recently put forward by a nongovernmental, bipartisan group in an attempt to end the present stalemate over a national energy policy.

Drivers of a Renewed Interest in Nuclear Power

There are a number of factors that are driving a renewed interest in nuclear power plant development. Climate change concerns and recent increases in natural gas prices are obvious immediate drivers in the nuclear policy debate. Other factors such as advances in nuclear power technology and responses to the spread of nuclear weapons capability may take longer to unfold. The cumulative effect of these and other factors could tip the policymaking debate in favor of expanding nuclear power in the United States.

However, it is not obvious today whether nuclear power is on the verge of a revival. At the end of March 2005 there were 441 operating power reactors worldwide. Over the past 12 years, 33 reactors have been shut down internationally while 54 have been connected to the grid. Out of the operating plant total, 103 are located in the United States; the average age of those plants is 22 years.[51] (Schnieder 2005) The last unit to enter commercial operation in the U.S. was TVA's Watts Bar Unit 1 in May, 1996. The last successful order for a US commercial nuclear reactor was in 1973. Only 31 countries, or 16% of the 191 UN member states, operate commercial nuclear reactors. About three quarters of the nuclear energy produced in the world is generated in the United States, France, Japan, Germany, Russia and South Korea. (Schnieder 2005, p.37)

Global Development Activity

New nuclear energy development activity in a number of countries and some substantial financial commitments suggest that the long-discussed nuclear revival may finally be underway. China appears to be making the most significant commitment to expanding its

[51] In the U.S. the 104th unit is expected to resume operations in a few years.

nuclear power plant fleet with plans to order 30 additional nuclear reactors, which would represent $50 billion or more in capital spending. Other Asian countries including Iran, India, Japan, Taiwan and South Korea are considering or already building new nuclear capacity. In fact, 22 of the last 31 commercial nuclear reactors to become operational are located in Asia; and 18 of the 27 new plants under construction are located in Asia. The U.S. recently announced an accord with India to permit increased access to nuclear power technology for India's civilian nuclear reactors. (Harding 2004a) In Europe, Finland's TVO has started work on the first nuclear power plant to be built on either side of the Atlantic in a decade. The French parliament has given its approval for a new nuclear plant, the first to be approved in France since the mid-1990s. At the same time policies in other countries with substantial nuclear development, such as Sweden and Germany, has oscillated from commitment to phasing out nuclear power to tolerance of existing plants.

Roadblocks to a full-fledged international nuclear revival remain, however. Key problems include nuclear weapons proliferation concerns and power plant costs. The United States has actively opposed Iran's efforts to purchase nuclear power plants from Russia as that country also builds a sophisticated fuel enrichment program. Although Iran has signed the Nuclear Nonproliferation Treaty, past experience in North Korea and political sensitivity toward the Iranian regime have raised U.S. concerns about Iranian nuclear development. The U.S. continues to seek negotiations with North Korea, which "withdrew" from the Nuclear Nonproliferation Treaty and expelled international monitors before possibly reprocessing spent fuel for plutonium for weapons. (The U.S. agreement with India, noted above, appears to be an exception: India has refused to sign the treaty and yet the country has a history of using civilian nuclear reactors to produce plutonium for weapons.) China's plans to build so many nuclear power plants could also present the global community with proliferation concerns. The *Economist* recently made the following editorial comment:

> So, if the economics are so unpromising, why is so much nuclear capacity being built? Some of it, in China, for instance, may be the result of mixed motives. China could be after the technology that America wants to deny it. Security might also be a factor: energy importers may want a proportion of their needs met by sources over which they have control." (The Economist 2005)

Recently, the U.S. House of Representatives vetoed a $5 billion loan from America's Export-Import Bank to assist Westinghouse in bidding for China's nuclear power plants.[52] (The Economist 2005)

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[52] Leonard S. Hyman in The Rudden Energy Strategies Report of April 18, 2005 noted that China had $440 billion of foreign reserves, all earning low interest rates. He speculated that China might want to finance nuclear power plant construction in the US.

Federal Support

Reinvigorated federal support is a major element of the perceived revival of interest in nuclear power. The Department of Energy released a "Roadmap to Deploy New Nuclear Power Plants in the United States by 2010 ("Nuclear Power 2010") in October, 2001. Nuclear Power 2010 program is a joint government and industry cost-sharing effort intended to identify sites for new nuclear plants, develop advanced nuclear plant technologies, and demonstrate new regulatory processes leading to a private sector decision by 2005 to order new nuclear power plants for deployment in the U.S. by 2010.

DOE claims that barriers to deployment of new nuclear power plants include significant cost and schedule uncertainties associated with the new, untested processes for siting, licensing and operating new nuclear power plants. A study by the University of Chicago echoes DOE's claims that the principal economic barrier to nuclear power will be the ability to address the costs associated with building and operating the first few nuclear plants. (Harding 2004a) The Nuclear Power 2010 program sets a goal of reducing installed costs for advanced reactor designs to the range of $1,200 to $1,500 per kW.[53]

DOE offered four major recommendations for actions that could significantly enhance prospects for building new nuclear reactors in the U.S. this decade. The four recommendations include:

1. Implement a phased plan of action by means of industry and government collaboration, as follows:

    - Phase 1: Resolve the uncertainties regarding the new plant regulatory approval process. (10 CFR,52)

    - Phase 2: Complete the engineering and design work for at least one light water and at least one gas-cooled reactor in time to allow start of plant construction on a schedule that could achieve deployment by 2010.

    - Phase 3: When regulatory approvals and completed engineering are in hand, construct and deploy multiple commercially viable new nuclear plants by 2010.

2. Place appropriate government financial incentives for privately funded new plant licensing, design and construction projects. Establish a basis for industry and government collaboration.

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[53] The *Economist* notes that nuclear vendors claim the new designs will cost only $1,500 per kW of installed capacity under ideal conditions with no delays. The *Economist* claims a more realistic assessment is that the new plants will probably cost close to $2,000 per kW. (The Economist 2005) Such an assessment is consistent with the experience with recent nuclear power plants constructed in Asia. Even these costs are below the MIT Study's estimated current "overnight" construction costs of $2,000 per kW. (Overnight construction costs exclude debt and equity obligations and are specified in constant dollars of the year production begins.)

3. Conduct an assessment of the nuclear industry infrastructure and its implications on near term deployment. Determine key areas of infrastructure weakness and the actions needed to accommodate them.

4. Develop a National Nuclear Energy Strategy that supports implementation of the National Energy Policy (NEP). This strategy would create a working structure for the aspects of the NEP applicable to new plant deployment and would cover topics such as roles and responsibilities, priorities, funding principles and processes, and required administrative and legislative actions. (DOE 2001a)

As part of the Nuclear Power 2010 program, Exelon Generation, Dominion Energy and Entergy Nuclear have applied to the NRC for early site permits at an Exelon site near Clinton, Illinois; the Dominion Mineral plant at North Anna, Virginia; and the Entergy Grand Gulf Nuclear Station in Port Gibson, Mississippi, respectively. The federal government is paying half the costs of developing these applications for early site permits. If permits are issued by the NRC, they would be good for 20 years and could be extended for another 20 years. None of these companies has actually committed to building a new plant. (Cochran 2004,p.4) Additional incentives are being considered in pending energy legislation. These incentives have been designed to either address "the first of a kind" engineering costs or the benefits of reduced carbon emissions.

Three consortia have formed to test the new government plant siting procedures and lay the groundwork for possible plant construction. None of these consortia has committed to building a power plant. The largest of the consortia is NuStart Energy Development LLC, comprised of 14 utilities and two vendors, General Electric and Westinghouse, which have competing reactor designs. The utilities have each pledged $1 million per year for seven years. The other consortia are led by Tennessee Valley Authority and Dominion. The consortia are pursuing different reactor designs: General Electric's advanced boiling water reactor and economic simplified boiling water reactor, and Westinghouse's Advanced Passive 1000. (Energy Notes 2005) Finally, Framatome ANP and Seimens AG have formed an alliance to build nuclear reactors in the United States. Between them they currently design and install 30% of the world's nuclear generation capacity and provide nuclear fuel to 46% of it. (Silverstein 2005)

Advances in Nuclear Energy Technology Development

While commercial nuclear reactors in the U.S. are based on light water reactor technology, there are a number of alternative choices for type of fuel, type of reactor, coolant, and whether the overall fuel cycle is "open" or "closed". In a "closed" fuel cycle the spent fuel is reprocessed and recycled after use in a reactor, while in an "open" or "once through" cycle spent fuel is disposed of after a single use in a reactor core. Either type of fuel cycle can be based on either uranium or thorium as a fuel. Different fuels and fuel cycles can be used in different reactor types, such as light water reactors (the predominant type of commercial reactor operating in the U.S. now), or heavy water reactors, supercritical water reactors, high temperature gas-cooled reactors, liquid metal and gas fast reactors, or molten salt reactors. There are a variety of trade-offs among these potential combinations in terms of economics, proliferation implications, safety, and actual operating experience. (MIT 2003, p.31)

Nuclear power plant technology has continued to evolve since the 1970s, when the current U.S. reactor fleet was designed and permitted. This evolution in technology is reflected in industry terminology that defines “generations” for different types of reactors. For example, the 103 operating nuclear power plants in the U.S., built in the 1970s or early 1980s, are referred to as Generation II reactors. Later designs, the Generation III Advanced Boiling Water Reactors, were built in Japan and Taiwan in the 1990s. Looking toward the future, industry sources believe Generation III+ reactors such as economic simplified boiling water reactor and Advanced Passive 1000 could be built as soon as 2010. Generation IV reactors, representing more radical design changes, are unlikely to be available before 2020 or even 2030.

This evolution in technology is frequently neglected in discussions about the nuclear power industry. Professor Per Peterson of the University of California, Berkeley made the following comment:

> It’s not widely understood that there have been and is continuing to be significant evolution in nuclear technology. These new plants, such as the Gen. III+, are a big step forward from previous technology, particularly in the area of safety and physical security…. The reactors that are operating now were designed primarily to withstand severe natural events. New plants will be designed specifically to withstand terrorist attacks.

Newer technologies will generally employ “passive” rather than “active” safety systems. Passive safety systems rely on heat exchangers designed to use natural convection cycles to circulate water to remove heat from the core, while active safety systems rely on pumps, emergency diesel generators, and similar equipment to circulate water for cooling. While the mechanical components of active systems require frequent inspection and maintenance, passive systems in principle would reduce the need for aggressive surveillance or maintenance procedures. (Energy Notes 2005)

Per Peterson has said, “We estimate another reduction by a factor of two in materials inputs to be possible [for the Gen IV Advanced High Temperature Reactor which should lower capital costs]. It is interesting, especially if these plants can be safer, more resistant to proliferation, and sustainable.”

Others are less sanguine about the potential benefits of technological advances. For example, Jim Harding has written a report on the pebble bed modular reactors, an advanced gas-cooled design currently under development in South Africa. He concludes that Eskom’s (the South African utility) short and long range cost estimates depend on a large number of “… extremely optimistic safety, reliability, and efficiency assumptions. Commercial experience with gas-cooled power reactors began in the United Kingdom in 1956, with Calder Hall, and ultimately led to the construction and operation of forty plants in the UK, Japan, Spain, Germany, France, and the U.S. Their record in meeting cost, reliability, and lifetime performance expectations is decidedly mixed." (Harding 2004b)

Based on its review, the MIT Study concluded:

> "We have found, and based on current knowledge, do not believe it is realistic to expect, that there are new reactor and fuel cycle technologies that simultaneously overcome the problems of cost, safety, waste, and proliferation." (MIT 2003, p.5)

That said, MIT is supportive of additional research on HGTR reactors:

> "The high temperature gas-cooled reactor is an interesting candidate for reactor research and development because there is already some experience with this system, although not all of it favorable. This reactor design offers safety advantages because the high heat capacity of the core and fuel offers longer response times and precludes excessive temperatures that might lead to release of fission products; it is also has an advantage compared to light water reactors in terms of proliferation resistance.' (MIT 2003, p.9)

However, the MIT study concluded:

> "We believe the lead time to carry out RD&D requirements for HTGR licensing, and at least several years of operation by one or more demonstration plants, will add up to 15 to 20 years before rapid, commercial deployment can be expected. Given this lead time, we expect that two thirds or more of the fleet through 2050 with be LWR." (MIT 2003, p.49)

Climate Change Concerns

On June 1, 2005, Governor Schwarzenegger signed Executive Order S-3-05 setting greenhouse gas (GHG) emission reduction targets for California. The Executive Order called for a reduction of GHG emissions to 2000 levels by 2010, then to 1990 levels by 2020, and a reduction of GHG emissions to 80% below 1990 levels by 2050. As the Governor signed the Executive Order, he declared, "I say the debate is over. We know the science. We see the threat. And we know the time for action is now." (Schwarzenegger 2005)

The Governor's concerns are shared by the international scientific community. For example, the Intergovernmental Panel on Climate Change (IPCC), an international scientific body which periodically assesses the state of climate change science, found in 2001 that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." (IPCC 2001) In May 2001, President Bush asked the National Academy of Science (NAS) to assess the veracity of the IPCC findings. According to the NAS, the IPCC assessment "accurately reflects the current thinking of the scientific community on this issue." In addition, the NAS reported that "GHG are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising." (NAS 2001)

As a result of these conclusions on climate change, some are advocating that the nuclear option not be closed in light of global climate concerns.

Comparative Costs

Nuclear power is not now competitive with alternative power sources. When MIT performed an interdisciplinary study of "The Future of Nuclear Power" in 2003, it found concerning the costs of new nuclear power plants:

> "In deregulated markets, nuclear power is not now cost competitive with coal and natural gas. However, plausible reductions by industry in capital cost, operation and maintenance costs, and construction time could reduce the gap. Carbon emission credits, if enacted by government, can give nuclear power a cost advantage." (MIT 2003, p.ix)

MIT's assessment of possible reductions in nuclear energy costs and a comparison to existing coal and natural gas technologies is summarized in Figure 35 below.

Figure 35: MIT Nuclear Energy Cost Comparison

Comparative Power Costs

CASE (Year 2002 $)	REAL LEVELIZED COST Cents/kWe-hr
Nuclear (LWR)	6.7
+ Reduce construction cost 25%	5.5
+ Reduce construction time 5 to 4 years	5.3
+ Further reduce O&M to 13 mills/kWe-hr	5.1
+ Reduce cost of capital to gas/coal	4.2
Pulverized Coal	4.2
CCGT[a] (low gas prices, $3.77/MCF)	3.8
CCGT (moderate gas prices, $4.42/MCF)	4.1
CCGT (high gas prices, $6.72/MCF)	5.6

a. Gas costs reflect real, levelized acquisition cost per thousand cubic feet (MCF) over the economic life of the project.

Source: (MIT 2003, p.7)

Even with the identified possible cost reductions, the nuclear costs are higher than expected case coal and natural gas generation costs. MIT's assessment indicates that nuclear could be cost competitive with coal, if there was a carbon tax (or a GHG cap and trade system) of about $100 per ton of carbon dioxide.

The cost comparison is also sensitive to the projected price of natural gas. As shown in Figure 36 below, the MIT study examined the competitive position of nuclear power relative to gas-fired combined cycle power plants as a function of gas prices and carbon taxes. With gas prices close to the MIT 'high" gas price case, the study found nuclear power plants can be competitive with a reasonable combination of carbon taxes and price reductions. However, in the MIT Study "low" gas price case there is a substantial price gap and the required carbon tax would have to be closer to $200 per ton. While there is substantial uncertainty about the future price and availability of natural gas, the conventional wisdom is leaning towards relatively high future gas prices.

Figure 36. Comparative Costs Under Carbon Tax and Natural Gas Price Scenarios

Table 5.1 Costs of Electric Generation Alternatives
Real Levelized Cents/kWe-hr (85% capacity factor)

Base Case	25-YEAR	40-YEAR
Nuclear	7.0	6.7
Coal	4.4	4.2
Gas (low)	3.8	3.8
Gas (moderate)	4.1	4.1
Gas (high)	5.3	5.6
Gas (high) Advanced	4.9	5.1
Reduce Nuclear Costs Cases		
Reduce construction costs (25%).	5.8	5.5
Reduce construction time by 12 months	5.6	5.3
Reduce cost of capital to be equivalent to coal and gas	4.7	4.4

Carbon Tax Cases (25/40 year)	$50/tC	$100/tC	$200/tC
Coal	5.6/5.4	6.8/6.6	9.2/9.0
Gas (low)	4.3/4.3	4.9/4.8	5.9/5.9
Gas (moderate)	4.6/4.7	5.1/5.2	6.2/6.2
Gas (high)	5.8/6.1	6.4/6.7	7.4/7.7
Gas (high) advanced	5.3/5.6	5.8/6.0	6.7/7.0

Source: (MIT 2003, Table 5.1)

Financial Competitiveness of Capital Intensive Technologies

Nuclear power plants are capital intensive facilities with a substantial construction period. Most of the US reactor fleet was built in the 70s and early 80s, a period of severe inflation with historically high debt costs. Inflation and higher debt costs rippled through to the construction costs of capital-intensive projects such as nuclear power plants, and in some cases increased their installed costs by over an order of magnitude.

Today's U.S. economy is facing deep federal budget deficits, a substantial trade deficit, and the inflation pressure of oil and gas price spikes. Nevertheless, interest rates remain relatively low at this time. Whether this will remain the case for the extended period over which new nuclear investments might be made is uncertain. The MIT study did not present a sensitivity case that reflects current financial conditions. However, there is no guarantee that such conditions would be sustained through the construction period of a new facility. Indeed as Peter Rigby of Standard & Poors noted, "The industry's legacy of cost growth, technological problems, cumbersome political and regulatory oversight, and newer risks brought about by competition and terrorism concerns may keep credit risk too high for even [federal legislation that provides loan guarantees] to overcome." (The Economist 2005)

Former Critics

Some environmental advocates, such as Peter Schwartz and Stewart Brand, who have generally been considered opponents of nuclear power, have now either muted their concerns or have expressed new willingness to consider nuclear power options. Leaders of respected environmental organizations such as Environmental Defense and the World Resources Institute have made positive statements about nuclear power as part of a response to global warming. The newfound willingness to consider nuclear power appears to stem in large part from a determination that solutions to the challenge of global climate change must include nuclear power as a non-greenhouse gas emitting source of power. Although not yet ready to offer full-fledged support for nuclear power, Environmental Defense is willing to at least consider an expansion of nuclear power capacity in the United States because "climate change is so serious that we need to consider every low-carbon energy option." (Chameides 2005) The World Resources Institute likewise stops short of embracing nuclear power but also will not reject it out of hand because the threat of climate change is so significant.

This change in stance by some former opponents has generated heated debate and at least a few rebukes from other environmental advocates. One group that remains staunchly opposed to nuclear power is the Natural Resources Defense Council. Thomas Cochran, director of NRDC's nuclear program opposes "continued and massive taxpayer subsidies to mature energy technologies, including nuclear power." He also would "internalize the environmental cost of nuclear, and fossil-fueled power plants by supporting a cap on CO_2 emissions, and tightening regulatory controls on aquifer polluting coal and uranium mines and uranium mills." Finally, Mr. Cochran has called for "a repeal of the inadequate EPA regulatory standards for the Yucca Mountain site." (Cochran 2004)

What remains to be seen is whether this sometimes-qualified support for nuclear power from those perceived as former critics will lead to the development of a new generation of nuclear power plants. To date, support has generally been framed in terms of the role of nuclear power as part of a portfolio of power options or as not closing off the nuclear energy option rather than as the primary new generation option. This position is represented below in a statement by Stewart Brand of Global Business Network. An opposing view is provided in a statement by Amory Lovins of the Rocky Mountain Institute.

For and Against: Two View Points

Now we come to the most profound environmental problem of all, the one that trumps everything: global climate change. Its effects on natural systems and on civilization will be a universal permanent disaster.

Can climate change be slowed and catastrophe avoided? They can to the degree that humanity influences climate dynamics. The primary cause of global climate change is our burning of fossil fuels for energy.

So everything must be done to increase energy efficiency and decarbonize energy production. Kyoto accords, radical conservation in energy transmission and use, wind energy, solar energy, passive solar, hydroelectric energy, biomass, the whole gamut. But add them all up and it's still only a fraction of enough…The only technology ready to fill the gap and stop the carbon dioxide loading of the atmosphere is nuclear power.

Nuclear power certainly has its problems – accidents, waste storage, high construction costs, and the possible use of its fuel in weapons…. The storage of radioactive waste is a surmountable problem …. Many reactors now have fields of dry-storage casks nearby. Those casks are transportable. It would be prudent to move them into well-guarded centralized locations….

Nuclear could go either way. It would take only one more Chernobyl-type event in Russia's older reactors (all too possible given the poor state of oversight there) to make nuclear taboo permanently, to the greater detriment of the world's atmospheric health. Everything depends on getting new and better nuclear technology built. (Technology Review 2005)

- Stewart Brand

Peter Schwartz and a few other longtime friends have become so enchanted with nuclear theology that they now suggest, in a bizarre kind of reverse projection, that market-oriented analysts like [Rocky Mountain Institute] are somehow in thrall to quaint and impractical notions. They claim that we economic rationalists, not they, are misled by a false antinuclear theology that blinds us to the manifest superiority of the nuclear god.

…As a student of this subject since the early 1960s, when I thought nuclear power sounded like a good idea, I've always been, and am today, open-minded about the possibility that it may have hidden merits. But based on the literature and on deep practical experience of electric efficiency and production in scores of countries, I see no evidence that nuclear power, using any technology, under any political system (let alone an attractive one), is or promises to become an economically, technically, or socially sound energy solution.

I read many slick nuclear polemics and sweeping qualitative claims, but see no analysis backing up their key assertions, such as alternatives' being small and slow, which the market contradicts. It's no good claiming we need all options. We have only so much money. The more urgent you think it is to protect the climate, the more important it is to spend each dollar to best effect by choosing the fastest and cheapest options—those that will displace most carbon soonest.

In short, I'm unmoved by nuclear theology. In God we trust; all others bring data. Show me the numbers." (Lovins 2005)

- Amory Lovins

Ending the Energy Policy Stalemate

The National Commission on Energy Policy is a nongovernmental, bipartisan group funded by several non-profit entities.[54] A key objective of the NCEP is to advance national discussions on America's future energy policy. To this end, in December 2004 NCEP released a wide-ranging report, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges*, that outlines six broad policy goals. These goals, taken together, are put forward to ensure an affordable and reliable supply of energy for the United States. Briefly stated, the NCEP's six goals are as follows:

1. Improve oil security
2. Reduce risks from climate change
3. Improve energy efficiency
4. Expand energy supplies
5. Strengthen energy supply infrastructure
6. Develop energy technologies for the future

NCEP's Energy Policy Recommendations

The goals are not new nor can they be achieved simply. The NCEP offered specific recommendations to achieve each of the six goals. Importantly, the NCEP did not offer a menu of recommendations from which to select specific options; rather, the NCEP views the recommendations as a package or portfolio of elements.

- To improve the nation's oil security, the NCEP recommended increasing and diversifying world oil production, reforming America's Corporate Average Fuel Economy program, and offering incentives to encourage the manufacture and purchase of hybrid and advanced diesel vehicles.
- The NCEP would address the risks of climate change by implementing a mandatory tradable-permits system and by linking U.S. emissions reductions efforts to the efforts of other countries.
- Energy efficiency could be improved by updating and expanding efficiency standards for appliances, buildings and equipment; by combining better standards with technology incentives, consumer information programs, and research; and by promoting energy efficiency in the industrial sector.

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[54] The organizations providing funding or support to the National Commission on Energy Policy are the William and Flora Hewlett Foundation, the Pew Charitable Trusts, the John D. and Catherine T. MacArthur Foundation, the David and Lucile Packard Foundation, and the Energy Foundation.

- The NCEP recommended expanding energy supplies by focusing upon four energy sources: natural gas, advanced coal technologies, renewable energy, and nuclear power. For each of these four energy sources, the NCEP made specific recommendations for expanding the role of the energy source in America's overall energy mix.

- To strengthen the nation's energy supply infrastructure, the NCEP recommended lowering the barriers to siting critical energy infrastructure, protecting critical infrastructure from various types of security threats, supporting a diversified infrastructure portfolio (e.g. large-scale, distributed), encouraging investment in transmission and distribution for electricity supply, and establishing a multi-pollutant emissions reduction program.

- The NCEP encouraged the development of new energy technologies through increased government funding, incentives for private sector investments, international cooperation in investment programs, and incentives for the early deployment of four specific technologies (coal gasification and carbon sequestration, domestically-produced efficient vehicles, domestically-produced alternative transportation fuels, and advanced nuclear reactors).

The NCEP stated in its report that "no single technology, resource, or policy can solve all energy problems or meet all energy policy objectives." (NCEP 2004, p.41) Thus, the NCEP's recommendations to expand the nation's energy supplies focus upon four energy sources: natural gas including LNG, advanced coal technologies, renewable energy, and nuclear energy. Each of these energy sources could potentially play a critical role in achieving important policy objectives such as reducing the nation's vulnerability to energy price shocks and mitigating emissions. In the view of the NCEP market forces alone will be insufficient to support expansion of these four energy supply sources.

Benefits and Challenges to Expanding Nuclear Power

The NCEP cited four potential benefits to expanding nuclear energy's share of electricity generation.

First, nuclear generation can make a substantial contribution to efforts to cap and reduce greenhouse gas emissions in the U.S.

Second, the worldwide uranium supply is not subject to the same vulnerabilities as oil; uranium is relatively inexpensive and abundant.

Third, an increase in nuclear generation will mitigate natural gas supply pressures and potential price increases.

Finally, nuclear generation provides a high degree of reliability. The NCEP recommended supporting both existing nuclear plants and the development of next-generation nuclear technology.

Any expansion of nuclear energy in the U.S. would have to surmount four challenges, according to the NCEP. The four challenges are cost, terrorist attacks or accidents, radioactive waste disposal, and proliferation risks. The NCEP's perspective on each of these four challenges and recommendations to overcome each challenge are summarized below.

- Past expectations that nuclear power is not cost-competitive with gas-fired or coal-fired generation may no longer hold true. Nuclear power's cost competitiveness could improve substantially if the prices of other sources of power reflect their true environmental costs. To address the cost challenges associated with nuclear energy, the NCEP recommended the use of standardized designs, $2 billion in federal funding to support the research and development of advanced nuclear technologies, and recognition of the non-carbon nature of nuclear energy by including nuclear generation in renewable portfolio standards.

- Safety challenges for nuclear energy include both the threat of terrorist attacks and plant malfunctions or human error leading to a power plant accident. The NCEP recommended expansion of the NRC's licensing process to consider a plant's ability to resist a terrorist attack.

- New nuclear reactors are unlikely to be built until the federal government demonstrates an ability to sequester radioactive spent fuel. The Yucca Mountain geologic repository should be licensed and begin operations. The government should also begin the construction of dry-cask spent-fuel-storage facilities at multiple locations. Specifically, the NCEP recommended reforming the Nuclear Waste Fund and restoring monies previously diverted from the fund. Transportation of radioactive material should also be addressed with an emphasis on outreach at the state and local level.

- Without adequate safeguards and policies in place, civil nuclear generation programs could become sources of weapons-grade plutonium. A proliferation of weapons-grade material would jeopardize civil nuclear energy programs not just in the United States but in other countries as well. To combat the risks of proliferation, the NCEP endorsed an indefinite continuation of the current moratoria on commercial reprocessing of spent nuclear fuel and construction of commercial breeder reactors. The federal government should also support research and development efforts focused on advanced reactor technologies and fuel-cycle concepts that could potentially reduce spent fuel and make the diversion of weapons-grade material more difficult. Finally, the U.S. should work with other countries and agencies to prevent the proliferation of nuclear material globally.

CHAPTER 7: FINDINGS

The preceding chapters provide background and factual information on California's nuclear power plants and key nuclear issues but do not draw conclusions. This chapter offers some preliminary findings for consideration by the IEPR Committee. These findings are merely starting points for consideration, and parties are encouraged to submit rebuttals and their own proposed findings to the IEPR Committee. Given the complexity of some of these topics and uncertainties associated with some of the key variables, findings are not provided for some areas (e.g. going forward costs and benefits). Again parties are encouraged to submit evidence in these areas to assist the IEPR Committee in its deliberations.

New Nuclear Power Plants in California

At this time there are no pending applications for the construction of any new nuclear powers plants in California. There are no announcements of any plans or public pronouncements of interest in constructing a new nuclear power plant in California. The resource plans of California's utilities do not contain proposals for new nuclear power plants. Challenges for future development of nuclear power in California include overcoming high construction costs; availability of financing; seismic, security, and safety concerns; scarcity of water for plant cooling; and unresolved spent fuel disposal problems.

Therefore, the Energy Commission will not receive a license application for the construction of any new nuclear power plants in California in the near future.

California law prohibits the construction of a nuclear power plant in California until the Energy Commission finds that there has been developed and that the United States through its authorized agency has approved and there exists a demonstrated technology or means for the disposal of high-level nuclear waste, (PRC, 25524.2) and for plants requiring the reprocessing of spent fuel, the Energy Commission finds that the United States through its authorized agency has identified and approved, and there exists a technology for the reprocessing of nuclear fuel rods. (PRC, 25524.1)

Since such findings have not been made to date, we conclude that the Energy Commission could not approve a license application for the construction of any new nuclear power plant in California at this time. It is unlikely that the Energy Commission would be able to make such a finding in the near future.

Spent Fuel Reprocessing and Implications for California

California law prohibits the construction of any new nuclear power plants requiring reprocessing in California until the Energy Commission finds that the United States through its authorized agency has identified and approved, and there exists a technology for the construction and operation of, nuclear fuel rod reprocessing plants. Reprocessing is one of the technologies considered for the treatment and disposal of spent fuel.

At this time the Energy Commission can conclude that reprocessing is still substantially more expensive than waste storage and disposal.

At this time the Energy Commission can conclude that reprocessing still has substantial implications for U.S. efforts to halt the proliferation of nuclear weapons material.

At this time the Energy Commission can acknowledge the recommendations regarding reprocessing and implications for nonproliferation of nuclear weapons made by the National Commission on Energy Policy, the Harvard University Project on Managing the Atom, and the Massachusetts Institute of Technology's interdisciplinary study, The Future of Nuclear Power.

Waste Storage and Disposal and Implications for California

California law prohibits the construction of any new nuclear power plants in California until the Energy Commission finds that there has been developed and that the United States through its authorized agency has approved and there exists a demonstrated technology or means for the disposal of high-level nuclear waste.

At this time the Energy Commission cannot conclude that DOE will ever operate the permanent repository at Yucca Mountain. Until the permanent repository at Yucca Mountain (or at an alternative location) either begins operation or can be credibly expected to begin operation using a demonstrated disposal technology, the Commission cannot find that the federal government has approved and there exists a demonstrated technology for the permanent disposal if spent fuel from these facilities. DOE's failure to license and operate a permanent repository has imposed substantial costs on California's consumers who have paid over a billion dollars for this service and have had to incur the costs of building and operating interim fuel storage facilities.

The Energy Commission should continue to monitor the federal high-level waste disposal and spent fuel storage and management programs with regard to their implications for California and for the Commission's ability to make the findings required by P.R.C. 25524.1 and 25524.2.

Consequences of Failure to Develop Yucca Mountain

California's nuclear plant-owning utilities "re-racked" the spent fuel pools at their nuclear power plants when the initial design capacity of the pools was reached and a permanent waste repository had not yet been built. Although re-racking the pools provided extra storage capacity, there are engineering and safety limits to this approach. The spent fuel pools at SONGS and Diablo Canyon are approaching these limits.

Both SCE and PG&E have proposed to build or have already built on-site interim fuel storage facilities where spent fuel will be temporarily stored in dry casks. The spent fuel produced by Humboldt Bay, Rancho Seco and SONGS 1 will be or already is stored in on-site interim fuel storage facilities. SCE's and PG&E's interim fuel storage facilities are sized to contain the spent fuel produced by SONGS and Diablo Canyon during the period covered by their current operating licenses. The design of these facilities is intended to permit the safe storage of spent fuel for decades after the expiration of the existing operating licenses. In effect, the facilities buy time to design, license and construct a permanent repository correctly.

California needs a comprehensive assessment of the implications of indefinitely relying on at-reactor interim fuel storage facilities.

PG&E has recently announced that it has initiated a study to assess how Diablo Canyon and Humboldt Bay would be affected by worst-case scenario tsunamis, where the worst case scenario will reflect the implications of the December 2004 tsunami in Asia. SCE has no plans for such a study.

The State should review the results of PG&E's study and the basis for SCE's decision that such a study would not be worthwhile.

The California Attorney General, Mothers for Peace, and others have challenged the NRC's decision concerning PG&E's application for a license to construct and operate an interim fuel storage facility at Diablo Canyon due to the NRC's refusal to consider the implications of terrorism in its NEPA assessment of this application. This challenge is pending at the Ninth Circuit Court of Appeals.

The State should consider other means to insure a study of the implications of terrorism is performed, such as a request to the Department of Homeland Security or the Government Accountability Office.

In the heightened security environment since September 11, 2001, increased attention has been paid to the vulnerability of nuclear facilities to potential acts of terrorism. Nuclear power plants are difficult targets due to their substantial containment vessels, but spent fuel pools and interim fuel storage facilities may be more vulnerable. There has been a vigorous debate between the NRC, the National Academy of Science and the Government Accountability Office on this topic.

The State should consider the implications of these disputes.

Centralized Interim Fuel Storage

Some interested stakeholders have suggested relocating spent fuel from interim fuel storage facilities located at nuclear power plants to a regional centralized facility which would have better security. (Technology Review 2005) At least one such facility should be located somewhere in the western U.S. At this time there is a proposal to build such a facility in the western U.S.

The State should evaluate the viability of this option and assess whether California should anticipate that this interim facility will become operational.

Spent Fuel Transportation

Regardless of whether a waste storage and/or disposal facility becomes available on an interim basis somewhere in the West, or in a permanent repository at Yucca Mountain, it will be necessary to move the spent fuel from the existing locations at reactors in California. Moreover, if the spent fuel is transported to a centralized interim location, then it will ultimately have to be transported a second time to a permanent repository.

California will incur significant costs in facilitating the safe transport of nuclear waste shipments and in providing emergency response services. California's fees for these services are lower than other states and may be inadequate to cover state costs incurred for shipment activities such as shipment inspections and escorts.

The State should perform a comprehensive assessment of the potential costs associated with the transport of spent fuel within and through California to insure that its fees are adequate to cover costs.

Numerous federal and state agencies are involved in regulating the transport of nuclear material and ensuring certain safety standards are met.

The Energy Commission should continue its participation in collaborative processes at the national and regional level to ensure that the State's interests are represented.

The Energy Commission should also continue to coordinate the California Interagency Transport Working Group to plan, prepare and initiate state needs assessments for spent fuel and other large radioactive shipments in California.

Costs and Benefits of Operating Nuclear Power Plants

California's existing nuclear power plants provide about 13% of California's energy supply. Since the marginal fuel in California is gas, nuclear power plants displace significant amounts of natural gas. A significant reduction in the demand for natural gas should reduce the price of natural gas in both California and nationally. Since power production at nuclear power plants does not require combustion of fossil fuels, there are reduced emissions of air pollutants and greenhouse gases (GHG), providing environmental benefits.

Estimates of the values of different benefits to California as a result of operating the existing nuclear power plants are summarized here:

1. The direct benefit of obtaining energy and capacity from California's nuclear power plants is on the order of $1.5 billion to $2.5 billion per year (as measured by the cost of replacement power).

2. The indirect benefit of reduced demand for natural gas ranges from $218 million to $581 million per year.

3. The social benefits of reduced air emissions including greenhouse gas emissions range from \$67 million to as much as \$678 million per year.

The types of costs that are likely to be incurred if California's operating nuclear power plants continue to run include the following:

1. The plants incurred significant costs for their initial construction and for post-construction capital additions. Ratepayers have almost fully paid for the amortization of these investments, so these costs are "sunk" (already paid for by ratepayers). Their "going forward" costs include significant investments, however.

2. Estimated revenue requirements for continued operation of these facilities through the end of each unit's license range from \$6 to \$10 billion for Diablo Canyon and from \$7 to \$16 billion for SONGS.[55]

3. Environmental costs would be incurred for the intakes and discharges of cooling water. (Panelists at the workshops will address the results of mitigation programs for these impacts.)

4. Shutting down SONGS could require significant investments in transmission upgrades or replacement generation capacity to maintain the reliability of the grid in southern California. The potential range of these investments has been estimated by SCE as \$287 million to \$673 million.

Careful accounting is necessary for a comprehensive assessment of the likely costs and benefits of operating these power plants through their existing licenses.

Preserving the output of the Diablo Canyon and SONGS power plants will require a number of likely actions. The steam generators and other major pieces of equipment will need to be replaced. It will be necessary to build and operate interim fuel storage facilities. It will be necessary to recruit and train a replacement workforce. Fuel supplies will be necessary.

The California utilities should explain how they plan to coordinate their nuclear plant outages and other generating units to assure adequate resource availability during the replacement of their steam generators. The State should ask PG&E, SCE, and SDG&E to describe their backup plans for the power from the existing nuclear reactors in the event that any of these facilities undergo extended outages.

In the heightened security environment since September 11, 2001, increased attention has been paid to the vulnerability of nuclear facilities. The substantial containment vessels at nuclear power plants should be less easily penetrated than spent fuel pools and interim fuel storage facilities, which due to their "softter" structures may be more vulnerable. There has been a vigorous debate between the NRC, the National Academy

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[55] The high end of this range includes \$1.4 billion in potential additional security costs.

of Science and the Government Accountability Office on this topic. Panelists at the workshops will address these concerns.

The NRC has responded by increasing the design basis threat for nuclear power plants, which SCE and PG&E estimate has increased their annual costs by $5.65 million and $5 million, respectively. Other interveners have claimed that additional security requirements could increase these cost estimates by almost twenty fold, up to $1.4 billion per plant over the next 15 years.

Potential Expansion of Nuclear Power

Nuclear energy technology has continued to evolve since the current fleet of nuclear power plants was designed and built in California. Even without new orders for nuclear power plants in the U.S., construction continued internationally, particularly in Asia.

When the Massachusetts Institute of Technology examined the competitive position of new nuclear power plants relative to either new coal or gas-fired generation, there was a substantial cost gap for nuclear power plants. Nuclear energy might become competitive if construction costs and lead times were substantially reduced, if a significant carbon tax was charged to coal and gas, or if gas prices increase substantially and remain high. However, it will be necessary to achieve these cost reductions while preserving or even enhancing safety and reliability.

DOE is providing funds for various utilities and/or consortia of utilities to develop applications for new nuclear power plants using advanced nuclear technologies. Such incentives could lead to one or more new nuclear power plants being constructed in the U.S. However, the nuclear industry has a long history in the U.S. of over-promising on costs and performance or attempting to scale up promising technologies too quickly.

The State should continue to monitor the status of DOE’s programs and at the appropriate time seek to determine the fuel cycle costs and performance of advanced reactors.

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